How can people's spatial behaviour be used to dynamically lay out content on multi-user, interactive screens, and how does this dynamic layout affect people's spatial behaviour?

by

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Authors Declaration

This thesis consists of my own work, with all material authored or co-authored by my own hand. This is a true copy of this thesis, which has been a long time in the making.

Statement of Contribution

This body of work has presented a series of contributions to the field of HCI and Computer Science, ranging through a number of design considerations and recommendations for Multiple Independent Simultaneous Users around Public Large Interactive Displays with a variety of layout approaches, and the design and implementation of a novel interactive digital system for data capture and display layout and adaptation.

The early chapters of this work describe how multiple low-level considerations of multi-user interactions around displays may be influenced by factors of displays during approach and on-going use, leading to emergent social phenomena, organisations, and effects on experience. Investigations of these factors gives considerations around feedback and presentation of content to support natural organisations of users.

The work goes on to consider the design and implementation of a full scale lab-based test system to support multiple independent user interactions, and identifies how natural organisations of users form at large displays as the result of relative entry position, presenting a number of factors of on-going use found through interaction and feedback between users and the system. This leads to clear implications for multi-user systems and a series of recommendations around their situation, design, and use.

Observations of learned behaviours are then presented to help identify optimal adaptation strategies of the display relative to on-going formations of users, as reported in the earlier findings and observed in natural organisation. An investigation of these strategies identifies multiple aspects of their use and a series of design recommendations in applying them to multi-user systems as components of both effective application and user experience.

A novel approach based in simulation is then applied to investigate the influences of feedback in supporting approach to a mapped and predicted application of informed adaptation, identifying strengths and weaknesses in this approach and establishing a significant body of further work.

Abstract

This thesis aims to explore the influencing factors of layout and presentation changes of large interactive and adaptive displays in multi-user interactions and social organisation. While significant bodies of work have considered the interactivity of digital displays to identify phenomena of use, these have been conducted in localised isolation, and do not address the wider ecological impacts for the influences of emergent organisations of simultaneous use where a system or display may support this.

Through considerations of how display presentation and layout can influence the emergence of social organisations, a series of iterative lab-based studies have been carried out to assess and inform a number of interaction modalities. This leads to a series of design recommendations around a system-led approach in presenting a mechanism to support approach behaviours and the maximised utility of a large display, whilst mitigating conflict between social boundaries and impact to user experience.

This has identified a range of factors in both the mechanisms of natural social organisation and supporting layout changes and adaptations in maintaining user experience leading towards wider use, scaffolding features of the environment, on-going use, and adaptation within a novel system-led approach. This has presented clear implications to the field, and identified significant areas for further research to refine the subtle factors of interaction which have been identified here.

Acknowledgements

"Thank you, everyone."

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Abbreviations

Multiple Independent Simultaneous Users (MISU's): A collection of users independently engaging with the system at the same time.

Public Large Interactive Display (PLID): A display of significant dimensions to allow multiple simultaneous user interactions when accounting for personal space and gestural engagement.

Human Computer Interaction (HCI): An established field of research within computer science.

Functional Formation (F-Formation): Identifiable organisations of users co-located within and around tasks or points of interaction.

Software Development Kit (SDK): A collection of software tools packaged in one installable program, the examples here is proprietary and ships with the sensors selected.

Identifier (ID): A unique value assigned to an individual or object.

Display Handler (DH): A software module within the physical system development designed to manage all aspects of the projected display.

(Chapter 8: Study 4 - Predictive Study)

The following shorthand descriptions are used to annotate tables of findings and are referred to as part of the consideration of findings [NCF, NDS, NDF, NCS, RCF, RDS, RDF, RCS]

(N/R) – C – (F/S) – (Novice/Repeat) – Clustered entry condition – (First/Second)

(N/R) – D – (F/S) – (Novice/Repeat) – Distributed entry condition – (First/Second)

As such;

NCF – Novice Clustered First

RDS – Repeat Distributed Second

Etc.

Chapter 1: Introduction

This chapter introduces the underlying concepts of how Multiple Independent Simultaneous Users (MISU's) interact with and around Public Large Interactive Displays (PLIDS's) showing digital content as a form of ecological interaction, where aspects of the space, on-going use and factors of display presentation and layout all act to inform use. This will set out a background summary of current understanding found in both Museum Studies and Human Computer Interaction (HCI), and the potential shortcomings in the use of these systems. This will lead in to the Research Question and problem areas and opportunities which are to be investigated throughout this thesis, the methodology and approach in achieving this, assumptions underpinning the work, and finally a summary of the chapters which follow.

1.1 Background Summary This thesis presents an investigation of the role of changes in layout and presentation of content on large interactive displays, with regard to breakdowns and conflict in multiple user interactions. By addressing prior knowledge of multiple user interactions with digital surfaces, an investigation and iterative exploration of display factors and their relation to entry and approach behaviours is carried out, informed and driven by the social behaviour and organisation of users around multiple points of interaction at a large display. This leads to an understanding of how forms of layout changes and interactivity can provide a mechanism to address breakdowns or conflicts during multiple user interactions, and ultimately provide a scaffolding of layouts, feedback, and points of on-going interaction accounting for wider entry, approach, and engagement.

Sociological studies have identified aspects of spatial behaviours based on layouts and on-going social use, where the nature of use can define how and where awareness and interaction may take place. This is further refined in consideration of interactions in museum studies with and around objects and digital surfaces, and how conflict and collaboration can lead to boundaries and breakdowns in the interactions of multiple users. Where understanding of these factors can lead to embedded solutions in design, they do not address real time support of these issues in the user experience or in the localised interaction and resulting natural organisation of those in the space, where there is the potential to support wider engagement and mitigation of boundary or conflict formation.

In examples of breakdowns or conflicts in multiple user engagement these factors are emergent in the nature of use and user behaviour and form part of the shared user experience. While breakdown and conflict are expected components of an interaction, they can both be related to the evolution of the interaction with an object in real time, such that on-going behaviours and organisations during use can indicate towards mechanisms for conflict avoidance and breakdown repair through structured organisation of the interaction. In identifying and addressing issues through an awareness of current use and evolving engagement a greater utility can be achieved by mitigating the potential for these factors to influence an on-going engagement, and in turn provide structure to the context of the engagement within the wider space.

In scaffolding on-going use to provide structured wider potential for engagement found through awareness of interaction, boundaries can be managed via external digital channels in conjunction with social awareness and affordances of organisations of users. Where avoidance and repair are possible in a localised interaction through changes in layout, there are also consideration of how new users are able to gain awareness and engage. With approach towards an on-going configuration defining how or where to engage, where possible outcomes may result in boundaries, conflict or breakdown for any user within the interaction design, the wider context of approach must be addressed. Movement or flow patterns in large spaces relative to configurations of current use will define entry points and potential for approach, so requiring consideration of how approach can be managed as an extension to organisation of use at a display.

This body of work will consider how natural organisations form at large interactive displays and how on-going use and approach can influence boundaries, conflict, and breakdowns between multiple user interactions. Through iterative investigation of these organisations and behaviours, a series of layout adaptation strategies and the use of feedback will be considered based on extreme emergent use cases. These strategies will then be investigated in relation to user configurations and approach behaviour as a system-led mechanism to support avoidance and repair of conflict and breakdown in multiple user interactions.

1.1.1 Prior work and understanding

When addressing interaction in public spaces we must consider the "Ecology of Interaction" (Heath et al., 2002), such that interaction and engagement unfold due to the social and physical characteristics of the space and its content. This can include but is not limited to; actions of groups and individuals, social interactions, the situation of objects, forms of interactivity, and the overall physical layout of the space. These components go to form the decision making and observed actions of those in a space, and while complex and interrelated, provides a grounding for interpretation of how and why decisions are made.

Within these spaces large interactive digital surfaces will draw the attention and engagement of multiple users. While a display may be designed for a single point of interaction, multiple users may engage with the object through observation or awareness, social organisation, or attempting to share in the experience. This social use of a display and points of interaction leads to a number of observed phenomena around sharing, collaboration, co-operation, competition and breakdowns, which may not have been initially designed for or expected, but are present in the interaction non-the-less.

These complex interactions between users are considered in Museum Studies as examples of shared and co-orientated experiences, with this being documented as an integral component of the formation of experience and factors of learning and understanding. Many of these phenomena are described in literature as aspects of natural use, organisation, and behaviour and give a richer interpretation of how users may engage with a display and other users. Within this we see inherent behaviours and expectations around factors of formation at public shared displays that can lead to conflict and breakdown, such as co-orientation, sharing, turn-taking, shoulder surfing, leading to collaboration or competition, etc. where these factors may not be wanted or desired in the interaction design or user experience. Where the role of these factors is not fully accounted for in models of engagement for structured interactions with adaptive content there is the potential to explore how structured adaptation of content, layout and interactivity play a role at all levels in forming parallel interactions.

> "How do you feel when you are looking at something in a museum or gallery and somebody stands behind you?"

Wider social interaction and engagement behaviours are of particular interest where Shoulder Surfing and Turn Taking (Brudy et al., 2014) are seen as direct factors of multiple user interactions with and around objects. As the result of limited space, lack of understanding, and social pressures, these factors exert pressures on use and reduce experience through boundary conflicts, requiring users to manage their actions resulting in collaboration or competition. This can be further compounded when considering wider spatial factors such as awareness, leading, and honey pot effects, which act to further influence the co-operation, collaboration, conflict and breakdown of interactions around objects as an inherent component of public spaces. Addressing adaptable content, there is no clear relationship detailed in structuring or scaffolding an on-going series of interactions and how this may support or mitigate boundary formation, or the role structured boundaries play in informing wider spatial behaviours.

Where localised interactions describe how users interpret on-going use, resulting in natural organisations, the formations and factors of use result in distinct behaviours and organisations around the display as the result of the structure and presentation of content and interactivity. Boundaries of local organisation then present a physical-social relationship to this structure, where awareness, behaviour, and use; “Isovists” (Dalton et al., 2013), “Roles in interaction” (Peltonen et al., 2008), “Zones of Use” (Brignull & Rogers, 2003), can inform approach and movement towards social organisations and points of interaction. Where user organisations describe the local use of a space or display, the resulting boundaries describe how the wider space can be used in forming parallel engagements, so extending the structure of content presentation out in to the wider interaction space.

This is explored in the idea of multiple displays or points of interaction and the concept of “Situation” and “Chained Displays” (Ten Koppel et al., 2012), where the orientation and physical position of a display directly affects use and engagement. This can be on the scale of multiple individual large displays, handheld, or ubiquitous technologies. Multiple points of interaction will influence how local formations and boundaries arise between users at these points, and so change how users interpret entry, approach and movement when forming a parallel interaction to structured content. While each display will have its own situation and formation of users, these will influence one another, giving a clear need to consider how social organisations influence the space, but also how changes to display situation will influence wider spatial factors of flow, movement, and engagement.

Configuration of displays will specifically affect how users are able to approach, engage and interact, such that co-operation, co-orientation, collaboration, conflict and breakdowns are the direct result of the nature of use and organisation. Identification of these factors can then be found through observation of Proxemics, F-formations, Zones-of-Use, etc., to describe the space and interpretations of possible engagements between multiple users, where static and dynamic changes in these organisations can describe on-going use, available space for movement, and points of entry. With an understanding of how organisational factors describe behaviours, it stands that altering factors of the space will influence them also, yet it is not clear which influencing factor of space would be more valuable to consider, in either locally structuring or scaffolding on-going interactions to manage boundaries, or structuring interactivity to support approach and engagement.

When considering multiple displays, either large or handheld, there is a minimum space of engagement required given the nature of the interaction, with museums and galleries offering a more managed experience with considerations for expected use, approach, dwell time and group experiences. The minimum space defines how single users or groups may use a display, but may not account for social conventions of space, as described by Proxemics, F-formations and social organisation. This goes to influence how multiple users might co-orientate and form engagements around configurations of displays, such as “Chained Displays”, giving consideration of how local organisations may represent what is going on but not what is possible as formations of users create boundaries to further engagement.

This consideration for a minimum spatial envelope in forming an individual or co-orientated interaction then describes expectations of boundary formation which are exhibited through social behaviours such as F-formations and Proxemics. Through an awareness of these factors to a display layout, feedback and localised structuring can be applied to inform, manage, mitigate and repair boundary conflict towards more stable formations of situated use. In leading users towards more clearly defined scaffolded organisations this then provides a contextual structure to further explore the roles of interactivity and adaptation for wider entry, awareness and approach.

For larger outdoor spaces, such as shopping areas, thoroughfares or public transport centres, the movement and interaction patterns with and about these displays, as well as the type and nature of displays may alter greatly. This leads to a wider consideration of where and why a display may be situated, how it may be used, and the forms of interaction being portrayed. These altering scales offer an interesting series of considerations for how changing presentation and layout will influence movement, groupings and engagement within a space, as well as considerations of high demand for space and points of interaction and the social conventions that are applicable as the result of layout and interaction presentation given the situation.

This Digital-Social relationship of use to layout and presentation both defines and is defined by the nature of the space and on-going use. Simply transplanting a display or experience does not ensure the same use case for a multitude of factors, but it stands to reason that defining the nature of the interaction can influence actions and behaviours in the same way that the use of space will define how the display may be used. With changing on-going engagement between the display surface and users influencing and informing behaviours, this presents a mechanism to structure the physical and social organisation of a display layout in managing and supporting expected or intended outcomes based on forms of interaction and their impact in wider movement, flow, and engagement behaviours.

This intentional management of display layouts allows for multiple interactions and mitigation of conflict or breakdown where users are able to interpret the intention of the system in supporting layout changes and multiple interactions. Within this field there is a limited understanding of how users may respond to varying factors of natural and structured display presentation, yet there are examples of how dynamic changes to a layout can influence local “constellations” (Beyer et al., 2014) of use, but there is no further investigation of what these changes then mean to the wider use of physical or social space. This then requires an investigation of the influences of a structured or scaffolded layout to direct interaction and group formations and the wider spatial impact these formations impart to decision making in the on-going engagement of others.

Where factors of content layout and presentation in a social setting influence awareness, learning and engagement behaviours (Müller et al., 2009), this has not accounted for dynamic changes and the relative social organisation and behaviour of on-going users across a single large display surface, nor how these might influence and inform the situated display space. Specifically, our current understanding of the effects of boundaries of collaborative and competitive local organisation in drawing wider awareness and engagement through managed presentation of content is not clearly understood. While there are many local considerations of multiple co-orientated user at a display seen in literature, the wider physical and social configuration of space during entry, awareness, approach and engagement is lacking, such that we do not know how locally scaffolded presentation and layout will influence on-going interaction, and how these then influence, inform, and structure further approach behaviour.

Through observation and identification of how natural formations adjust towards new states of interaction during multiple co-orientated engagements, social organisation and behaviours can be more clearly related to a set of managed layouts. This can suggest either a set of factors for where and when adaptation of a display layout can reduce conflict and breakdown, or where changes may lead to an optimal output condition to achieve management, mitigation and or support of natural use of a large display surface.

In identification of formations, behaviours and states of engagement, there are clear indications of “roles” and “Zones-of-Use” to describe how individuals use spaces around displays and for what reason as they pass through various stages of engagement. This gives clear indication that a relationship between localised behaviours can start to describe how the display is used, but also how informed layout changes may influence on-going interactions and future use of space without introducing or relying on social factors or further boundary creation.

The emergence of known spatial use and local engagement at points of interaction leads to considerations of user trajectories (Benford et al., 2009) and how designed and expected outcomes may be subverted or managed through external factors of users and the display space. By addressing this issue there is the opportunity to identify and relate changing factors of behaviours and displays as informing factors of saffolded layouts in structuring use and broadcast greater meaning and intent for the approach and engagement of others. This supports repairing breakdowns and avoiding conflicts between multiple users where there are multiple engagement trajectories taking place.

As engagement is formed through the entry, awareness and approach, there must be particular emphasis on the initial physical configuration and manner in which multiple users are entering and engaging across a number of social conditions. This requires considerations of natural organisation in entry and developing use, structuring influencing factors of layout adaptation, and the role and influence of emergent formations to approach and engagement to structured interactions. In understanding how display layouts are related to on-going use it is possible to consider informed real-time changes and the affect this has to further approach and engagement. This presents the opportunity to investigate and understand the role of display layout in managing conflict and breakdown of multiple independent simultaneous users around large multi-user displays based on social behaviours either at the display or across the wider space.

1.2 Research Question

With consideration of the background understanding, application areas, potential use cases and gap in knowledge leading to the area of investigation, we can now consider the overarching research question in addressing the problem space:

How can people's spatial behaviour be used to dynamically lay out content on multi-user, interactive screens, and how does this dynamic layout affect people's spatial behaviours?

This will now be described as a series of objectives and sub-questions leading to the overall approach in answering the research question;

1) Identify and evaluate the range and impact of factors of display and interaction at surfaces in multiple user scenarios to inform issues of conflict and breakdown around use.
    a. What are the multi-user and display factors that lead to issues of conflict and breakdown with and around public displays?
    b. How can factors of use be related to layout and presentation designs to further explore the user behaviour and response?
    c. What are the roles of layout and presentation in influencing behaviour?
2) Develop a system capable of evaluating a range of layout and presentation factors during multi-user interactions to inform the use of these factors in natural behaviour.
    a. What are the minimum requirements of a system to evaluate a real world scenario?
    b. How do aspects of entry and feedback influence the natural use of an interactive display and what is the impact upon user experience?
    c. Which factors of layout adaptation can be related to approach behaviour and on-going display phenomena?
3) Ground the role of system-led adaptation as a mechanism to influence natural interaction.
    a. How are the system led adaptation approaches related to natural formations of users and user decision making?
    b. How and when are adaptation strategies appropriate, based on user experience?
    c. What are the leading factors in user decision making when considering display feedback, social interaction or adaptation?

These three objectives now describe the three stages of the overall approach in answering the research question. These objectives are further evaluated in the Problem Summary and Objectives section with the intended research approach detailed in the Approach and Methodology section, both of which can be found below.

1.3 Problem Summary and Objectives

Ecologies of interaction and user experience are formed through social engagement with and around objects. Within these engagements there are barriers, breakdowns and conflicts which arise from multiple users across a number of different types of interaction (direct manipulation, social engagement, turn-taking, learning, shoulder surfing, zones of use, roles, etc.). With a finite limit in the object design relating forms of interaction and potential for use, conflict and breakdown in interpretation and engagement lead to ineffective use and poor user experience from that which was intended or possible.

If we consider the natural social behaviours and interactions around display surfaces, there are a wide array of factors identified in how natural social organisation comes about in collaboration, co-operation, competition and conflict resolution. These social mechanisms are currently observed but not acted upon or represented in a supporting or system-led manner, where technology may provide an informed mechanism to manage these issues as they develop in relation to the design and potential for use of a large digital surface. These are most apparent in extreme use cases, such as large numbers of users to a single point of interaction or independent co-located displays, and are documented as phenomena of user engagement and experience to highlight interesting factors of natural use.

Problem 1) In extreme use cases where there are more users than may have been considered in the design of an object, there are likely to be many examples of conflict and breakdown in user experience, including shoulder surfing, turn-taking, and boundary conflicts to name a few. There are documented phenomena of how conflicts and breakdowns may manifest through approach and parallel engagements of other users both locally and across the wider space, but these are not addressed or accounted for in the potential design considerations of interactive systems.

Improvements in both display and sensing technologies offers the opportunity to support much larger and interactive display surfaces. In scenarios where a large multi-user display may be used, there are limitations in the ways these are understood and engaged with by users, leading to extreme cases and examples of conflict and breakdown at a larger scale.

Opportunity 1) Consider how extreme cases develop around large displays and the emergence of conflict and breakdown. This can then be related to mechanisms for managing layout and presentation of content to inform the design and usability of large displays.

There is a rich body of examples of behaviours of multiple users at and around display and the forms of interaction with and between one another. These describe natural organisation, co-ordination, co-operation, collaboration, error handling and conflict resolution. These do not, however, go on to describe the conflict and breakdown of interaction with much larger surfaces which may support multiple independent points of interaction, and there is little understanding of the critical aspects of the display and social behaviours which lead to extreme cases of interaction and distribution.

Within the local and wider cases there is limited information and understanding of entry, awareness, approach and engagement as the result of social organisation and behaviour at and around displays. While there are models of engagement and examples of movement around displays in use, this does not fully consider the role of either the display or user behaviours where a large display is under-utilised given its dimensions. In particular, it is not clear how a display itself may structure the layout and presentation of content to influence or inform use relative to local social organisation and so impact the overall engagement of the interaction area.

This leads to considerations of how localized structure of content might inform organisations of users around single or multiple points of interaction, and present mechanisms to facilitate boundary management and repair during conflict and breakdown. Further, structured and managed content layout and presentation offer the potential to influence user towards known cases to better facilitate a wider socio-spatial organisations.

Problem 2) There is limited understanding of how aspects of presentation and layout on a large display may change relative to the current use case and the influence this may have to on-going use, in particular during entry and approach behaviour of additional users where multiple users are already engaging with the display. Where on-going use can be scaffolded to provide localised structure to interactions, the role of these local structures and forms of interaction and activity on a display in entry, awareness, and approach are not currently related.

With factors of conflict and breakdown present in multi-user interactions there is a need to address the reasons and mechanisms of natural organisations which lead to boundary formation stemming from entry and approach, relative to layout, presentation, and developing social organisation which result in conflict and breakdown and under-utilisation of the display space. This can be further extended to consider how changing aspects of the display as factors of feedback and feedthrough may continue to influence and inform entry and approach behaviour relative to on-going organisations and behaviours, with informed changes being applied directly as the result of known configurations of on-going use.

Opportunity 2) Consider and present clear understanding of how experience and organisation forms during entry and approach for multiple users, and how layout and presentation influence this. This is extended by identifying social behaviours and organisations related to these factors and applying system-led mechanisms and interventions. These would need to be investigated relative to known configurations of users and to user experience in the overall use of a system in describing how social organisation, factors of on-going use, and components of system-led feedback and feedthrough work to influence decision making and approach and engagement behaviours.

1.4 Approach and Methodology

This section first describes the overall approach in answering the research objectives, followed by a brief summary of the specific methodologies employed.

The overall approach is broken down in to several stages, with a number of observational and sensitising steps to ground the work in literature, followed by an iterative process utilising the specific methodologies being described later to derive design recommendations and factors of investigation. These stages are split over the two main problem areas and opportunities, described above, with the early sensitising and investigation work as well as the first iteration of the test system addressing problem 1 and opportunity 1, followed by a focussed, iterative investigation of layout and presentation and their roles in influencing and managing interaction behaviours to address problem 2, with the outcomes providing key findings for the study as described in opportunity 2.

These stages are briefly outlined and detailed in the below figure (Figure 1-1) and are as follows;

1. Literature review to identify the limitations in current knowledge and problem cases to be addressed.
2. Field work to identify aspects of behaviours with and around digital displays which offer insight in to the problem space.
3. Sensitising work to consider aspects of Human Computer Interaction (HCI), content presentation and layout which directly influence the nature of interaction around displays, and to inform the initial development of a digital system as the basis for the following investigation.
4. Methodology - A three step iterative investigation built upon HCI methodologies to relate factors of Responsive and Adaptive display layouts and presentation to social behaviours and organisation, allowing an informed application of layout changes as a mechanism to support and manage conflict and breakdown relative to identified social behaviours.
5. A final iteration of the system to evaluate the potential use of layout change as a mechanism to construct a feedback-, feedthrough- approach for display interaction based on current use.

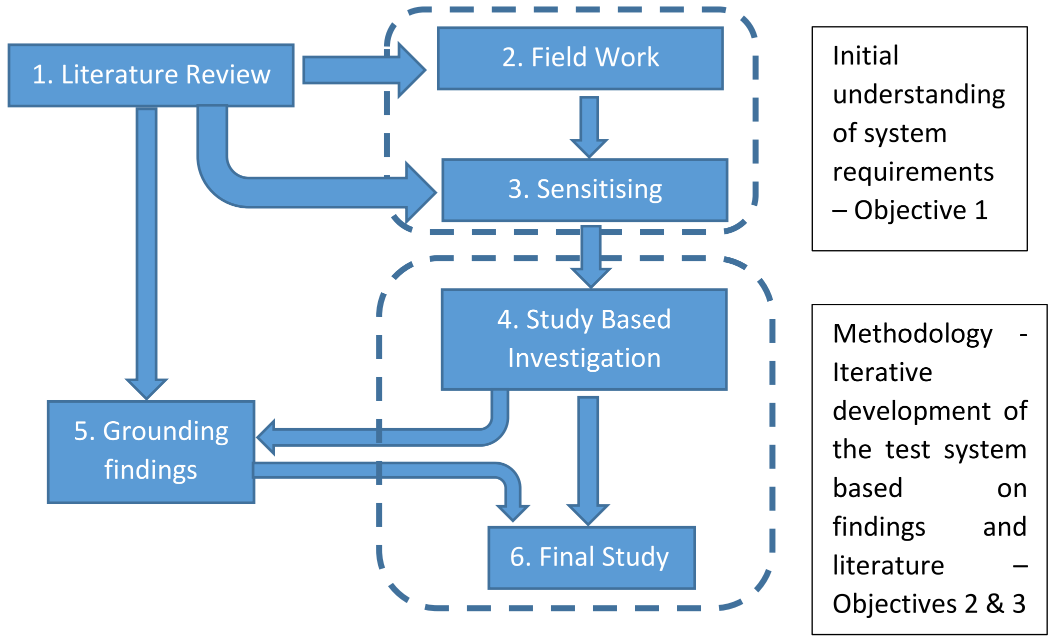


Figure 1-1: Overview of the approach taken.

The methodology in this thesis (indicated above) considers the iterative development of a test system to provide an overall evaluation in the role of display adaptations to user behaviours, as described in points 4 and 5 above. This draws upon two main research areas; Museum studies and Human Computer Interaction, both of which have been used to describe different aspect of user behaviours around artefacts in public space. The relationship between these two fields constitutes the basis of this research.

Museum Studies, focussing on public interaction in exhibition spaces, describes social interactions of individuals (or groups) around artefacts in a given social setting. This describes the interactions as a form of social behaviour (Reeves et al., 2005), and explores the use of social norms as design guidelines for development and deployment of interactive objects (Marquardt & Greenberg, 2012). The understanding of these behaviours aims to support more natural interactions with objects as a forms of human social engagement, and has led to the use of the Proxemics theory (Hall et al., 1968) as an underlying design concept in this investigation.

By addressing user-object (display) interactions as a social Proxemic interaction (Greenberg, S. 2011), the organisation of multiple users to points of interaction can be evaluated as either shared or independent of one another. Through this, separation of interaction phenomena of shared social spaces can be isolated and more clearly identified as components of the wider spatial behaviour relative to factors of the display layout. While these factors are inherent in any interaction, the identification of phenomena relative to each of the multiple individual interactions highlights conflict and breakdown between the function of the system and observed behaviours and user organisations.

Human Computer Interaction research mainly focusses on techniques that bridge the "gulf of execution" and "gulf of evaluation" as described by Hutchins (Hutchins, et al., 1985), with emphasis toward digital systems, where these techniques have been deployed around interactive public systems, including form factors (Bezerianos & Isenberg, 2012), situation (Fischer & Hornecker, 2012), adapting layouts (Schmidt et al., 2013), etc.. There is also a significant body of work concerning "novel" systems to support shared interactions (Coutrix et al., 2011) and non-co-orientated sharing of information (Bedwell & Koleva, 2007) in order to evaluate a range of group interaction scenarios. The study methodologies and lessons learned via these approaches have informed the design, testing and analysis of the work undertaken in this thesis.

Where many examples are considered as shared experiences, these focus on how groups engage with an object, yet it is also valid to consider the boundaries between users across multiple points of interaction. Identifying users as individuals allows for multiple points of interaction and a necessity for negotiation in addressing wider spatial behaviours, describing natural organisation and points of conflict and breakdown across the space. Single users present a clear set of observable and inferable behaviours and can report on individual decision making, while groups introduce severe complexity in both internal decision making and the wider impact of external behaviours towards them. While individuals will not share the group experience within the engagement, the spatial presence of multiple users defines emergent behaviour and gives multiple points of interest in changing layouts.

Throughout the investigation these methods would include; Ethnographic observation and thematic analysis during field work, further supported by Wizard-of-Oz trials during early identification and investigation of emergent user behaviours relative to layout and presentation factors, with video recording and semi-structured interview of user studies and further thematic and video content analysis used to highlight critical behaviours and user responses. Vignettes were used to describe specific themes within the final iteration and an empirical evaluation of key findings related to the mechanisms of layout adaptation derived from the investigation. Each component of the investigation is presented in more detail in the Approach and Methodology chapter and appropriate chapters throughout the work.

While an "In the wild" deployment would offer the most true-to-life results, it was not practical to explore the nature of interactions in this manner. Given the large number of simultaneous participants required to fully evaluate the range of factors which had been identified in the literature, there is no guarantee these numbers could be achieve spontaneously or consistently. Instead, the investigation will consider a laboratory based investigation focussed on aspects of entry position, content mapping and layout adaptation strategies relative to user behaviours. This method eliminated issues of significant numbers of simultaneous users and introduced standardised procedures for laboratory based studies, including between and within participants and semi-structured group interviews.

Following an iterative laboratory based investigation it was possible to evaluate the differences in novice and experienced users with a variety of adaptations strategies in specifically highlighting the impact of layout changes. Where novice users were introduced to various forms of interaction and their responses recorded relative to the display and social organisation, repeat users could be directly shown aspects of adaptation they were not familiar with, so focussing on user experience instead of interpretation and response. Repeat users were asked to perform as pseudo-actors in the adaptation trial by forming established configurations at the display to achieve a realistic scenario for novice users, but also to allow for adaptations of the layout to be experienced directly by repeat users. This was extended in the final iteration to have those in the space conform entirely to an acting role to evaluate the interaction and response of those then entering the space.

Results and analysis of the findings of these investigations follow the same approach described in the early field work and wizard-of-Oz studies detailed above, with the exception of an empirical evaluation of the findings in the final study as an approach towards describing how and why factors of the system worked. This was an initial attempt at separating out behaviours and forms of interaction seen in the final iteration, relating specific themes as detailed in the Vignettes, to factors of user and display behaviours. This was done to relate observed behaviours to a prediction and feedback based approach, where key changes in either user or display behaviour could be identified to further refine the use of feedback in supporting use and managing impact to on-going use.

As a consideration, Agent Based Modelling (ABM) and Simulation research address simple computer based models to rapidly evaluate a wide range of factors to identify critical aspects or emergent behaviours. A significant body of work to assess the use of space (Dalton et al., 2013), crowd phenomena (Treuille et al., 2006), and the role of groups (Vizzari et al., 2013) supports social science research through simple rule sets to model and predict interactions and outcomes as a useful mechanism to relate the real-time data potential offered by digital systems. While the methodology employed in this thesis does not draw directly on this knowledge outside of design theories as a part of the system design in the final study, the overall approach situates the findings of the study within both Social Studies and HCI to relate the two in a novel manner. This presents the opportunity to consider a potential feedthrough mechanism to complete the data flow loop between the three separate areas of understanding, see below (Figure 1-2).

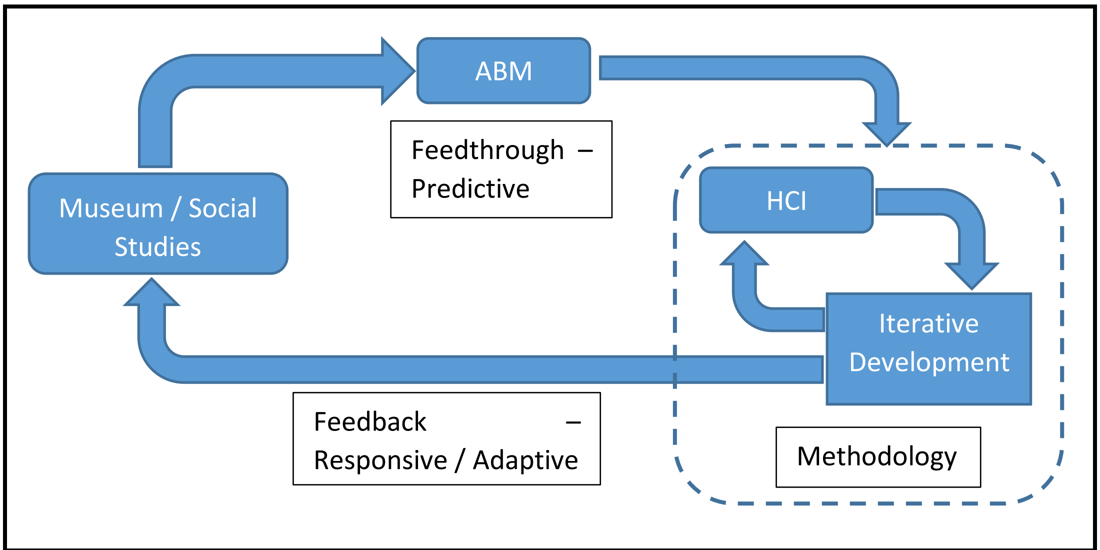


Figure 1-2: Situating the Methodology within the Approach to inform between fields.

This now presents an overview of the approach and specific methodologies employed throughout this thesis. A more detailed description of how each of these phases and the work undertaken relates to the objectives can be found later in the Approach and Methodology chapter and each study chapter where appropriate.

1.5 Assumptions underpinning the work

The following assumptions were made about the nature of user behaviours for both the field work and laboratory observations:

1 User responses would be homogenised across sufficiently large groups or repetitions, so supporting the concept of quantifiable clustered responses in forms of behaviour.
2 Engagement and response to various layouts and forms of digital displays would be the same relative to the physical configuration and situation, regardless of the nature of the content or interaction which is being shown.
3 User awareness, understanding and response could be simplified in isolation on a per-user case across MISU interactions and applied retroactively to defined modes of use.

These assumptions form the basis of the development of the problem space based on observations of natural behaviours in-the-wild and the development of specific factors of the iterative laboratory investigation. These assumptions were derived from general considerations of behaviour and examples from literature in supporting the research area.

1.6 Chapter Summaries

This section presents a brief summary and description of the chapters contained within this thesis. This includes the nature of the work undertaken, the critical findings and further questions or implications which are raised within the on-going investigation.

Literature Review: This chapter presents current levels of knowledge found in museum studies which have informed and lead in to areas of investigation within digital display interaction. This considers how underlying models of social behaviour, as a part of the ecology model of interaction, are described within HCI investigations and the varying forms of awareness, approach and engagement identified. The chapter highlights how competition, collaboration, conflict and breakdowns are all components of interaction, but also considers how conflict and breakdown may be limiting factors in the wider use of an object. This goes on to consider how a system-led interaction can support and manage these factors during use. This chapter supports the problem space and methodology within this thesis and draws attention to factors of further investigation in answering research objective 1.

Field work: This chapter addressed the prior short-comings identified in Museum Studies and HCI when considering digital interactions and provides a body of evidence to support the current limitations in knowledge. This chapter specifically identified the limitations of static content and single points of engagement, where previous findings identify phenomena but do not identify a mechanism to support users in preventing conflict and breakdown during engagement. This raises the question of which aspects of digital interactions present the most significant impact upon user behaviours and engagement to inform further study.

Study 1 – Wizard-of-Oz: This chapter considered the findings of the field work to assess the role of presentation and layout changes in group and multi-user interactions, where the aim is to better assess the range of impacts and simple design recommendations in utilising large digital displays. This work identifies the critical factors of use between both group and multi-user scenarios and presents a series of factors which influence engagement behaviour and user experience separately. Due to the wide ranging number of factors and observed responses the final recommendations are simplified to encapsulate as much of the information as possible. The significant outcome of this study was the relationship of presentation of display elements to social behaviours and organisation and the influences this had. These outcomes describe the need for a fully functioning interactive test system, the design problem space and requirements for implementation.

Study 2 – Responsive System: This chapter presents the first iteration of the full scale test system, including the technical evaluation, design and implementation process. The investigation focussed on aspects of entry and awareness as well as interaction and understanding between multiple users to identify and simplify the complex nature of social organisation. Influences of situation and entry position were investigated alongside content interaction to evaluate learning and resulting natural organisation based on emergent spatial use. Observed themes and user experience were used to identify critical aspects of the space and user behaviour in self-organisation in response to elements of display presentation. Extreme cases of interaction were specifically considered as points of conflict and breakdown to establish adaptation strategies as a mechanism to influence user behaviour.

Study 3 – Adaptive System: This chapter presents the second iteration of the test system, including the conditions of extreme use identified in the previous study and the required changes to the supporting software. The investigation focussed on strategies of layout adaptation relative to user formations found previously, and the role this had on decision making and engagement in multiple user interactions. The study considered two extreme use cases, where adaptation was applied as a mechanism to influence on-going use and approach behaviour, with observed movement and reported user experience used to evaluate the interaction. These findings present a series of design recommendations in the application of adaptation during real time use and form the basis of the final study, considering the application of informed adaptation relative to on-going formations.

Study 4 – Predictive System: This chapter presents the conclusion of the test system investigation, with the implementation of a linear modelling approach to predict the point of interaction and appropriate adaptation strategy during user approach. Users were asked to consider aspects of feedback during approach relative to identified user formations in supporting delayed system-led adaptations to evaluate the effectiveness of these strategies in real time. Observed engagement was compared with reported actions and experience to identify six interaction behaviours relative to the feedback presented. These behaviours indicate a number of design recommendations relating the nature of feedback given a user's approach behaviour and indications of current limitations. These findings offer interpretation for user behaviour as well as achieving a desired use of display space.

Discussion: This chapter presents an interpretation of the findings of this thesis as a series of critical observations found in each chapter, as well as a number of longitudinal considerations of behaviours relative to aspects of changing layouts. These points consider both the feedthrough and feedback aspects of display adaptation and the relative user interpretation as two separate components of the findings. The chapter compares points of interest in the findings to previous work and situates the extended understanding found here to distinguish the contribution to knowledge. The chapter concludes with a brief summary of the applications of this work to future research and the associated implications.

Conclusion and Future Work: This chapter revisits the contributions of this thesis to ensure the objectives of the research question have been addressed. This chapter then concludes the thesis and discusses several distinct areas for future research.

These chapters are now presented as the body of this thesis.

Chapter 2: Literature Review

When considering Public Large Interactive Displays (PLIDs) it is apparent there are a significant range of factors which contribute to the nature of interaction. For instance, physical layout of the space and situation of a display (Fischer & Hornecker, 2012), the layout and learning potential of content through presentation and awareness (Rodden, T. 1996), social configurations (e.g. individuals, strangers, groups, acquaintances etc.) in system use (Peltonen et al., 2008), user expectations and diverse forms of interaction (Hornecker, E. 2008) as well as interactivity and drawing user attention (Müller et al., 2010). This leads to a set of varied requirements when developing new forms of interaction for PLID's.

Further, the nature and presentation of content will influence how these systems can be used and by how many users simultaneously, however, this concept of Multiple Independent Simultaneous Users (MISU's) is still under explored in terms of the design and implementation of systems and the role of display layouts in influencing social and physical formations of users. While the physical and social aspects of spatial understanding are built around an ecology of interaction, the nature of MISU interactions with content and mechanism to draw relations between these bodies of understanding is lacking. This leads to considerations of the current areas of knowledge around social spatial behaviours, the nature of interaction and engagement with and around content, and mechanisms to begin to describe these factors in parallel as the first steps in investigating this problem space.

This chapter will now present an interpretation of the current levels of understanding found in the observation and interpretation of the physical nature of spatial use, the role of social interaction with and around artefacts and digital displays, and the nature of technologies in both design and human interpretation in forming multi-user experiences. This will ultimately draw parallels between the varying fields and provide a series of real world factors and digital relationships, leading to a bridge between the gap in knowledge and the basis for an HCI investigation around MISU interactions with digital displays.

2.1 Physical Space

Physical spaces and their use can be described in a number of manners, either relating the physical dimension and situation, on-going social use, the affordances granted by organisation, etc. To best understand the movement and behaviours in spatial use we must consider the actions of those in the space, as it is the emergent actions and interactions of the individuals which form the crowd and ultimately the use.

Early sociological observations by Hall sought to interpret the use of space through a variety of factors, such as organisation of affordances, flow patterns, ambient conditions, etc., however, a significant contribution to the field was the concept of Proxemics (Hall, et al., 1968). This addressed the manner in which people interact spatially, either in managing personal-social space or in organisational tasks, such as sharing space around objects or physical features and during movement. This concept of organisation in movement was later described by Livingstone (Livingston, E. 1987), where clustering behaviours were seen to influence on-going and emergent behaviours. These behaviours and outcomes have since been described in a number of observations and rule sets relating to the inclusion of digital technologies and the role that space has in structuring use and formation of engagement.

The concept of physical spaces defining the nature of behaviours through simple rule sets presents a powerful interpretation of spatial use. Understanding how an environment allows users to enter, explore and utilise space begins to describe the evolving use and emergent behaviours between multiple users in structuring interactions. Where multiple users are considered, this structure is expanded to address social influences in movement, boundary formation, and interaction design as inherent components of spatial behaviour.

This leads us to consider how aspects of physical spaces influence awareness, decision making, and spatial use to further expand the relation to social affordances as the underlying framework in the formation of interaction ecologies. This section will now consider; how physical space are organised, the role of these organisations in spatial decision making, sociological interpretations of spatial behaviours, influences in crowd dynamics, mechanisms of spatial object navigation, engagement with objects in space, and the situation of displays given spatial parameters. This considers how space is interpreted in everyday use and relates validated models of exploration and engagement to objects and displays in public spaces.

2.1.1 Layout of physical space

Layout and use of space are primarily addressed through the architecture and usability design. While the fundamental architecture will describe the physical affordance, the intended design for use will play a role in exploration. Tzortzi (Tzortzi, K. 2011), describes how aesthetic and spatial design relate to the experiences of users in exploring exhibition spaces. This presents framing of spatial composition relative to boundaries, with clearly demarked themes imposing movement speeds and control of visual horizons in drawing interpretation. Where weak boundaries provide alternative paths through a space and experience, local and discovered interaction leads to a heightened experiences through breaking the global route.

To describe the influence of physical layout it is important to consider how spaces are navigated globally to inform how localised factors may influence an individual. A study of train stations (Millonig & Schechtner, Developing landmark-based pedestrian-navigation systems, 2007), identified a range of both ego- and allo- centric landmark selection in decision making and problem solving through utilisation of references to landmarks relative to the individual and wider space respectively. This highlighted the point of the “path of least resistance”, or “reduced decision points” approach to navigation, with landmarks being used near or at decision points to allow local factors to be observed within the global task.

Where this study evaluated a train station, with significant numbers of visible landmarks of “high quality”, the selection of consistent or similar landmarks and pathways across users is extremely high. This results in a heat-map of both awareness and avoidance given selection and navigation approaches, as well as influencing factors in wayfinding. This is further evidenced by “Space Syntax” (Dalton et al., 2013), where simulated line-of-sight decision making resulted in accurate global movement patterns and localised boundaries in distribution and the use of the space. Both examples indicate inherent global and local boundary conditions are defined in natural use and suggests that awareness and interpretation of space will present a finite number of defined outcomes within the overall layout.

Suggestions of archetypical behaviour in movement and interaction (O'Connor et al., 2005), where consistent route planning and points of interaction describe likely interactions, help in considerations of observed behaviours being used to match individuals to likely outcomes based on specific actions and preferences in archetypal (subjective) decision making. This also expands the considerations for consistent behaviours in response to factors or tailored changes in the environment to support or influence wayfinding and route planning, as local factors can be modified throughout a space given a known set of parameters.

Emergent organisations and boundary conditions described by Fischer (Fischer & Hornecker, 2012) through a series of definitions for affordances of spatial use include relationships to displays and points of interaction, given an awareness of content layout and presentation. This is of particular interest considering spatial layouts as social and interactive spaces through the interpretation of localised and changing use. The "Zones of Use" characterisation of spatial position of actions and behaviours to objects (Brignull & Rogers, 2003), defined by physical affordance, shows emergent changes as the result of social boundaries implied by "Proxemic" decision making, defining social structure as a further component within the layout of a space. This leads to considerations of micro-macro effects of constellations and social organisation acting as additional perceived boundaries within spatial behaviours during navigation.

2.1.2 Crowd Dynamics

As points of interaction, movement, and use are defined through the physical layout, the social aspect of use brings additional considerations. The simplest interpretation, described in "Proxemics", is the physical position and orientation to indicate interactions and relationships between people, objects and the space. Yamori (Yamori, K. 1998), describes the micro-macro relationships within crowds, emphasising the importance of local clusters and interaction in the emergent behaviour, where strong social ties and inter-user relationships define the nature of the space through propagation.

Within these groupings we are able to identify how the need for intra-group communication has an extended impact upon crowd dynamics (Singh, et al., 2009), with the actions of a cluster conveying information to the space. The interpretation of these interactions is shown to lead to generic forms of behaviour in crowded pedestrian environments (Vizzari et al., 2013), as groups optimise and maintain cohesion relative to the activity or movement by altering their proxemic orientation, addressing co-operation, collaboration, and competition between various groups as boundaries of organisations are recognized in avoidance of conflict during spatial navigation.

This has been approached by multi-modal methods of data capture to identify underlying pedestrian behaviour in crowds and around static organisations (Millonig & Gartner, 2007), with many of the decisions and responses to interactions and stimuli appearing to be highly complex but also automatic. These generic responses or "rules sets", also known as heuristics in psychology, present a clear relationship between the dynamic behaviours of a crowd and the defined layout and use of space. This suggests that actions, organisations and formation of groups fundamentally define the use of space as boundary objects, supporting individual interpretation and negotiation for global decision making.

This is critical when considering up to 70% of a crowd may be composed of grouped individuals, where the influences of space, crowd density and route planning are seen to affect group formation (Moussaïd et al., 2010). This is further expanded when considering how points of interest and attraction act as waypoints for group behaviours in crowd situations (Anvari et al., 2013), so influencing movement patterns and clustering behaviours. Understanding how situation and user awareness towards objects and interactivity form within the layout of space leads to interpretations of group formation and evolving spatial behaviours as inherent aspects of object design.

2.1.3 Inclusion of objects

While layout and natural crowd dynamics offer a generalised understanding of movement, it is the formation and action of groups that is the underlying factor in emergent spatial behaviour. As objects act as points of formation and influence it is important to outline the nature of objects as points of interaction and how engagements form.

For any consideration of an object as a source of influence in decision making we must have some form of interpretation of its impact and behaviour, with frameworks to describe their situation and manner in which they may be discovered. Concepts of quantifiable metrics, in particular; Aura, Focus, Nimbus, Awareness, Adapters and Boundaries, as proposed by Benford et al.(Benford et al., 1994), consider a “pool” of objects contained within a shared space, providing a mechanism to relate their impact in drawing and inter-mingling forms of engagement as part of an ecology.

Within this framework there is no requirement for spatial interaction, as a quantifiable interaction can be found from the magnitude of relationships between each object to determine an overall engagement factor. Though interaction can still consider spatial metrics, such as proximity, as these factors are addressed in the manner of awareness or nimbus of an object, we can begin to interpret the interactivity and engagement of the space as a relationship of the configuration of the environment and artefacts in their own right. In this sense we can abstract away factors of the physical layout and inherent crowd response and only consider the object and the manner in which it is interacted with.

In particular, the nature of content and presentation go a long way to describe the impact upon exploration and engagement, with out-of-band information changing the nature of the relationships of objects and users (Huang & Mynatt, 2003). In considering the impact of a focussed interaction out to the local space, it goes further to say that adaptive digital content can indicate information that the users may not be able to identify by themselves. This takes the relationship of objects away from the concept of exploration and discoverability and introduces concepts of trust in the interaction and information (Kray et al., 2005), such that boundaries and breakdowns in use become directly coupled with the nature of the content, the manner that it is delivered to the user, and how delivery encourages further approach and engagement of others.

In addressing adaptive digital content as both a form of interaction and information, where physical layout and social organisation would otherwise run their course, this presents a mechanism to assess the direct and indirect impact of changes in aspects of content to influence wider use. Through considerations of the situation of the display and physical parameters of content presentation we can begin to address how social organisation and varying forms of interaction and engagement behaviours influence the local use and developing engagement of multiple groups or users.

Where we have previously considered physical and social space as defining the potential and probability of behaviours, the inclusion of a digital display as a focal object in its own right addresses the gap in understanding for how delivery and adaptation of display content might influence, inform and subvert expectations of actions and behaviours during entry, awareness, and approach relative to known factors of organisation. Specifically, identifying how content leads to the formation of boundaries, either through physical representations via scaffolding of the presentation, or relative to emergent social organisations and their spatial impact, and how interactivity, out-of-band or informative factors might influence boundary interaction in the wider space.

Where we see boundary formations as aspects of the physical space, social entities presented through group formations, and inherent personal-social boundaries, the way in which these form and are related to content presentation and delivery is still lacking in how adaptation of content is utilised with digital displays, or in how boundaries around personal space, group organisation, or aspects of ownership and territoriality are influenced or informed by content presentation and need to be managed.

2.1.4 Situation of displays

Physical situation describes a complex series of interactions, relating discoverability, awareness, and social organisation as part of the physical environment, but importantly these aspects go to define the interaction and engagement, and overall use of these systems.

Physical awareness and line-of-sight will mainly govern discovery and engagement with displays, expanding the Space Syntax approach of agent awareness, the Isovist "line-of-sight" model allows for interpretation of spatial organisation in the placement of displays (Dalton et al., 2013), describing the likelihood of identification. Building on the notion of an Isovist to indicate best placement, geometric considerations give the Visibility Catchment Area (Xie, et al., 2007) as a function of physical position. In the same manner as; Aura, Focus, Nimbus, Awareness of relative objects, this describes how individuals can identify content, however, this does not account for the process of interaction or engagement, which forms through inherent subjective decision making towards the content and social scenario.

Apparent "broad use" displays, such as advertising have been shown to attract limited attention, while digital display showing static content are ignored compared to equivalent posters or billboards. In comparison smaller displays are more likely to attract interaction, perhaps because they are seen to be more intimate in situation (Huang et al., 2008). Where these bodies of work indicate approaches to describe situation and content, they also indicate a need to further relate content design, situation and experience of display engagement as an extension of individual decision making and social context.

Some of these considerations are broached by addressing the expectations and thought processes of pedestrians whilst moving around public space and their considerations toward digital signage. This reveals issues of information overload and "banner blindness" toward content that is too rich or does not relate to local contextual use in a short interaction time. Considerations as to the signs owner and the intent of the content will also influence glance behaviour, in particular content around purchases or shop fronts will reduce the engagement (Müller, et al., 2009). The main outcomes are to address content to a more general audience, and also to consider the physical location and configuration of the signage i.e. angle to walking direction, installation height, levels of distraction, such that content delivery facilitates an interaction without an incurred workload being a part of the engagement process.

By encapsulating situation of displays and relationship to content it is possible to assess interaction and engagement as concepts of "Zones of Use" and "Transition" across zoned boundaries between behaviours to describe how and where displays are used, (Brignull & Rogers, 2003). This relates the physical parameters of the display to the interaction, and describes how changing factors of content relative to use defines a spatial nature, by either presenting an optimal viewing position or drawing attention and engagement through interactivity. With this in mind a single display can cast areas of engagement far outside the bounds of its physical situation and presentation in capturing the awareness of passers-by and drawing spectator attention.

With zones-of-use as a descriptor for display engagement, relationships of multiple displays directly change the social interactions of use between the displays. This can be either a perceived impact or a direct physical relationship in viewing or spectating an interaction. These “Chained Display” formations of physically co-located displays affects the zones-of-use between one another such that co-orientation between groups may no longer be possible or desired as the spatial boundaries between users come in to conflict (Ten Koppel et al., 2012). As such, configurations of displays or multiple local points of interaction should account for boundary relationships and conflicts in use through the nature of their design and structured content delivery to the display, however, this relationship is currently under-explored short of identifying its existence with no current relationship of display situation and content design and presentation being shown.

A six step framework for the situation of displays and advertising, where the relation to digital signage and displays describes how these might be interacted with when content is reactive (José et al., 2014), suggest the roles of content and interaction exist as inherent factors in design. This encourages engagement in the wider environment, where “Digital displays offer an opportunity for social modelling of adaptive content”, however, this is also underexplored and highlights the need for an investigation in to adaptive content layout and presentation of socially situated displays. In conjunction we find a need to identify how display adaptation will influence the social use of a single display, and also the need to then further explore and investigate the interplay of multiple adaptive displays or points of interaction relative to one another.

This now closes the loop in interpretation of displays as purely physical objects but presents a number of questions around the role of content and presentation, where we consider the nature of design and use being informed by social cues. By encouraging discoverability and use and causing changes in the interactions of those in the physical and social levels throughout the space, the limitations in this understanding lie in the known relationships of users to single points of interaction i.e. boundaries and conflicts when multiple users engage with a single object, and the dynamic interplay of many users across multiple points of interaction in forming engagements. This now situates the need for an understanding of changing structured content presentation and layout within the wider spatial behaviours of multiple user interactions, and how content presentation and layout can inform boundary creation but also act to influence boundary interaction between engaging users, leading towards a wider investigation of multiple points interacting between one another.

2.1.5 Physical parameters of presentation

Considering displays as global framing objects there is internal variability in the nature of content presentation and layout. Where situation will influence local positioning, the content will define the nature of the expanding interaction. In describing the influences of content it is necessary to consider the role of changing factors of content in the on-going behaviours of users.

Addressing the use of content we must contextualise the nature of the display and interaction, with the display; grabbing attention, encouraging interaction and dealing with issues of interactions and organisations of the public (when assuming interactive or adaptive content) (Müller et al., 2012). It is therefore critical to consider the design of content in how it is organised in supporting these factors (Bendinelli & Paternò, 2014).

Via interpretation of presentation there are "optimal locations" at displays which afford the most physically and socially comfortable position to observe and engage, where this can be affected by; changing size, changing position and blurring, to infer changes to the interaction position. Slower rates of change are found to be less effective, however, there is still a wider question of how adaptations and mappings to behaviour and response are understood (Alt et al., 2015). In particular issues are raised where multiple users are considered. Unless the adaptation is attempting to support all users, whether in a group or not, users are likely to be drawn to the optimal location resulting in potential boundary conflicts and issues of broken experience, as negotiation is required to manage interaction and the boundaries between "Zones of Use" of surrounding organisations of users.

Clustering around shared content leads to issues and inherent dislike of people standing behind you. Known as the "butt brush effect" (Underhill & Goldsmith, 2000), the actions of presentation draw multiple users to an optimal location, so diminishing the potential interaction. This is also seen in shoulder-surfing (Brudy et al., 2014), where an individual experience, or private content, may be exposed through exploration of a display by others. An investigation of adapting the presentation to indicate approach and glance behaviour looked to alert users to the assumed boundaries of ownership, but does not correct the layout to support parallel engagements. This leads to a fundamental issues of inclusion of a display in shared public space as the display will act to inherently draw attention and engagement through its inclusion, but introduces social issues around personal space and interaction in on-going use.

In examples of multiple users or "passing-by" a display, presentation of content holds a significant weight in both organisation and perception, where "corrected" orientations of content to a users' position allows extreme viewing angles and movement during engagement (Schmidt et al., 2013). While this supports distanced engagement there is a disconnect between the motion of content and the relationship to individual users, where content has been projected ahead of a user and then corrected to their viewing angle. These extreme engagements outside the context of expected use limit the ability to identify the mapping and corrected orientation in establishing a "landing zone" for interaction. Furthermore, the presentation is only visible to the user and has no relevance to others in the space, limiting a large display to a single user in a specific context creating a boundary to engagement.

In contrast, mirroring movement of content and full body representations are highly effective in drawing interaction, with slight leading effects achieving greater capture than pure mirroring. However, issues arise with the user' focus remaining tightly coupled with the representation and so additional content or factors of display change are not identified outside of the users focus (Walter et al., 2015). This allows for considerations of parallel interactions between users without potential interruption, but relative positions must be considered in how users may be aware of one another and articles of content presentation, as digital boundaries may be blurred but physical ones will supersede.

It has also been shown that size and position of content affect accuracy and recall when viewing from greater distances or acute angles. Selection of framing or bezels on displays are seen to influence size and position estimation and create difficulties in viewing multiple objects, which instead result in retreat from the display to minimise eye and head movement between content (Bezerianos & Isenberg, 2012). Careful consideration of content design is required when addressing how changes to layout or presentation will affect direct use, but also wider awareness and engagement in public spaces. Forms of interactivity will, by their nature attract attention, which in turn may impact upon the ability to maintain a desired interaction through the generation of physical and social boundaries.

The limitation of these investigations is the focus on the effect for isolated interactions, and not how these phenomena influence wider engagement as components of the space. The role of content presentation and layout has been clearly shown to be a key factor during formation and on-going use of digital displays, where structured or scaffolded content leads to know formations in use, where physical and social boundaries are organised through user negotiation. Yet there is a lack in understanding for how these factors interact for either multi-user of multi-points of interaction, or both when content is responsive or adaptive to on-going use. This suggests that further investigation of multi-users systems will provide a basis for multi-user multi-point of interaction system.

2.1.6 Summary

With factors of physical space, content, and the design of interactions accounting for wider movement behaviours, this now situates the specific details of content design within the physical organisation of space.

In considering physical situation of an interactive display as a key component in physical and social organisation in spatial behaviours, we can further consider how content presentation and layout are inherent component of localised organisation through physical scaffolding of content and social awareness of interactivity and engagement. Through comparison of these factors to known or expected entry, awareness, and approach behaviours as described in the physical situation of objects literature, we can begin to address the role of adaptive content as a factor of user decision making to inform content design and delivery.

The next series of considerations will address the social nature of spaces and the role this conveys into physical organisations. Where displays can be identified as centres of social organisation, this will be related back as a mechanism to both interpret and inform physical spatial behaviours.

2.2 Social Interaction

In considering public exhibition spaces the nature of use is formed through shared experiences and social interactions. Where the physical layout and affordances are shown to influence the inclusion of displays to act as focal points and pseudo-social entities, this now requires a more comprehensive consideration of social behaviours and the role of content interaction. The following section will consider; Interpretations of social organisation and interaction in museum studies, Social structures and the influencing factors of group dynamics, Communication theory of interaction between people in space, the nature of social interactions around interactive objects, and interpretations of formations of use.

This aims to define how social organisation can lead to awareness and engagement through social conventions, and where natural organisations are the result of negotiation between and across boundaries defined through acts of cooperation and competition. It is important to consider how these formations occur as an aggregated social response to situate the role of adaptive digital displays as both a responsive and driving factor in social behaviour.

2.2.1 Museum studies

The "Ecology model" describes all behaviours, interactions and experiences as formed by all objects, persons and interactions throughout the space (Heath et al., 2002). Here we can consider space as a series of relational factors, with factors of complexity increasing with the number of people and relationships they hold to one another and the objects contained within.

Where user-user interactions around objects can be interpreted through psychological and sociological lenses, there are limited numbers of interactions and mechanism in the consideration of user-object relationships (Heath & Vom Lehn, 2004). While we can consider non-spatially dependant formations of awareness, interaction and engagement towards objects through "spectator" interactions, it is not clear how this relates to the user-user organisations and spatial "zones of use" which form around objects given the number of factors and the complexity of user interactions. As varying forms of interaction and stages of engagement unfold there is a limited interpretation to the impact of local and distributed social organisation about an object, vs. the experiential aspect of forming an engagement, and no clear way to define how formations of use and engagement form relative to the nature of an object.

Following the lens of experience as a design consideration, relating how an object is considered and the resulting social organisations presents a mechanism to assess spatial behaviour. Acknowledging that there are wider factors in interpretation of space and interactions, there may be additional factors of design which can address experience more directly outside of functionality and transparency (Petersen et al., 2004). This asks if there are more powerful or supportive mechanism which may be incorporated in to spaces as the result of interpretation of social organisation in response to interactive system and content design to account for the formation of boundaries and how these are negotiated during approach and engagement.

Drawing together aspects of the wider space, on-going use, social learning and awareness, considerations of "Assemblies" of use, (Hindmarsh et al., 2005), promote the idea that user-object and user-user relationships can take many forms and must be considered in conjunction to address what the interaction is trying to achieve in a given context. This is expanded by "Space over Place" (Akpan et al., 2013), where social rules and conventions will determine the nature of engagement and interaction over the state of the object itself. This ties the nature of content to location and ecologies of engagement, such that the form of the space and content, may determine group behaviours.

This reiterates the points made in aesthetic framing and the nature of interpretation being conveyed (Tzortzi, K. 2011). The strength of local framing of content and use leads to a localised experience in the design of the environment, with consideration of the power of framing available in displays to support multiple points of interaction as part of both micro and macro ecologies. This points to a range of social organisations proving feedthrough and feedback both between and within interactions and leads us to consider how social structures define boundaries and the role of displays as framing mechanisms in forming and breaking them.

2.2.2 Communication through Social Structures

Observations of interactions in public spaces indicate that groups exert a significant influence over the nature and manner of subjective interactions for those outside of the group, as opposed to groups of non-connected individuals (Deutsch & Gerard, 1955). This presents a consideration of the "spectator" model, where feedback related to known organisations plays a role in the formation and actualisation of an engagement during the entry, awareness, and approach phases around organisations and interactions.

Topologies of interaction distribution (Ballerini, et al., 2008), give strong indications for potential behaviours when aiming for consensus in large unorganised systems. Consensus behaviours are further supported in road crossing, where individuals are able to act in rapid response to changes in state, while groups are seen to identify the potential for all member to achieve an action before it is carried out, (Faria et al., 2010). Here, the role of leading members is seen to catalyse the initial response and promote negotiating actions between external states or organisations. This is further supported when considering emotional cues, with in-group members better able to detect emotion than those out of group (Elfenbein & Ambady, 2002). This makes sense where familiarity is a corner stone of in-group social organisation.

This inward interpretation of behaviour and emotion related to state highlights both the engaging and dismissive behaviours of users in affected states. Where these states of behaviour can be described via a method of Personas' to accurately portray actions and behaviours of individuals and their transitions between states (Loke et al., 2005), where we can describe the influences of key personas' to the likelihood of group-wise actions and levels of engagement, and a wider spatial influence. While this suggests experience is formed through local interactions and the transmission of social cues, it also leads to an interpretation of organisations seen through proximity and orientation as the result of interpreted state for both within and out of group members, with several forms of interaction being identified through interpretation of space where strong social cues are present.

While Personas' and state convey compelling subjective information of group connectivity, resultant formations indicate a more immediate cue within social-spatial organisation. Functional formations (F-formations) (Kendon, A. 2010), describe the proximity and orientation of co-located groups to their actions, resulting in passive social barriers for open and closed group formations and points of shared interaction. Interest, exploration and approach by external users will test these barriers, where cohesive groups are likely to present a closed formation and strong social barriers, resulting in external "spectator" behaviours, vs. open formations of limited cohesion or independent users allowing approach, investigation and engagement around boundaries and points of interaction.

For a new user approaching on-going use at a single point of interaction there are the same considerations as if approaching a previously formed group; there is no clear indication that the group did or did not exist previously, and so social negotiation must take place across boundaries for conflict to be avoided. During entry, awareness and approach there are multiple factors of social organisation to be considered, with some more subtle or localised given the nature of the interaction, individuals and group-wise organisation. Consideration of focal points of interaction and the nature of the content displayed in these social settings offers a mechanism to assess how on-going use and approach may then interact.

2.2.3 Communication Theory - Gesture Encoding

Where formations prescribe social boundaries through physical organisation, the structuring of these formations are far more subtle. Interpretation of mood, manner or behaviour must consider how thoughts, beliefs and intentions are communicated between people. A comparison of communication in western cultures determined that 30-35% of communication is verbal, (Kirch, M. S. 1979), with action and intention coming via other means. Where Proxemics is a categorical factor in organisation, inter-relationships are more complex than proximity alone, with bodily cues, such as; eye contact, body lean, smiling leading to building communication, and trust managing coordination (Burgoon et al., 1984).

Structuring these factors people identify behaviours to manage their actions as part of co-location, where in-group factors form shared experiences and out-group manage boundaries and negotiation. The sentiment "the issue of interrelations between the structuring of the environment and the structuring of the interaction" (Luff, et al., 2003), draws parallels with bodily behaviour, spectating, and environment, to asks how factors of behaviour convey more than expressly intended, specifically disembodied gestures or actions relating to an object or display. With emotional or effected states then seen to transfer through inter-group connections and shown to be identifiable through digital observation (Dael et al., 2012). There are, however, limiting aspects within the transmission of information, with dominance affecting the flow of information and group cohesion (Jayagopi et al., 2009), but also acting to broadcast action and intent out in to the wider space.

Within this the use of gesture and action act to animate features of the environment as centres of coordination for formations and the wider ecology of spectators. "Participants 'read' or make sense of the actions of others through the ways in which they interweave conduct through particular features of the immediate environment; the embeddedness of action in the environment allows participants to discover what others are doing and why." (Luff, et al., 2003). As communication is formed around aspects of the environment we can build a picture of actions and response, and mechanisms for direct relations to components of the environment, with "… the capacity of participants to predict, anticipate, or prefigure the unfolding of events" (Kuzuoka, et al., 2004).

This is also seen through video conferencing, which can be considered as mirroring of users actions on an exhibition display to form co-orientation, where the role of subtle physical gesture plays the strongest role in drawing attention and implying meaning to actions and reactions (Norris et al., 2013). Through these forms of interaction at displays we can assess the relationship of use and feedback within the context of an interactive digital display as a mechanism to structure and project actions and behaviours of digital content to the wider space, whether this is through direct manipulation as a performer, or in response to changes as a spectator in informing boundary creation or management.

While subtle, these mechanisms define a significant proportion of the transition between spectator and participant states. While not currently computer "readable" we can consider before and after organisations i.e. it is not critical how changes came about but we know that they can, and begin to relate factors of user-object interactions to archetypical cause and effect within the space, to both interpret classifications and leverage subtle human communication through action and reaction.

While addressing social communication we must consider communication via displays, where interactions with and around content convey meaning and co-orientation. Shared experiences, including user-object-spectator, offer active and passive co-ordination with these mechanisms giving insight to how and why display changes influence social behaviour. Within this there is also the consideration of any formation, actions or behaviours being contextualised by the situation and presentation of content or interactivity shown, so providing an approach to relate action, behaviour, and organisation to structured or scaffolded content. This then allows for considerations of how entry, awareness, and approach behaviours form relative to these combined considerations and the ways in which content presentation and layout informs social structures and boundary negotiation.

2.2.4 Social interactions around objects

In interpreting how individuals approach and engage with displays we can consider an evolving combination of social, physical, cultural and content related aspects which define the dynamic process (Dalsgaard et al., 2011). This states, users engage with displays in a non-quantified manner, given a range of social, personal, and subjective factors of the piece and its current use, with sense-making coming through observation or physical interaction, where a person invests part of themselves in the content and interaction.

Personal investment is suggested through "performative interactions" with objects and negotiation with others, where freedom of exploration encourages playfulness in evaluation through the "joy of use". The organisation of experience is found through inclusion of others in the dialogue between themselves and the interaction, with experience formed via expectations of the system (Jacucci, et al., 2009), and explorative and playful investigations giving rise to an internalised sense of performance in a sense of both showing intent and claiming ownership. Considering interactions designed to cause affect and having no basis in emotional involvement, which is subjective (Fritsch, J. 2009), subverts the expectation of experience as a "gulf of execution" and "gulf of evaluation", to situate experience as a mechanism to evaluate change.

Relationships of performance as experience also act to identify points of interaction and draw engagement. The role of performative interaction, referred to as the "Honey Pot Effect", proposes social interpretation as a factors of social engagement and aspect of physical space in drawing attention and awareness to influence approach behaviour (Hornecker et al., 2007). This is expanded by considering "landing areas", as either points of interaction or locations where social engagement takes place. This may not include direct social interactions, but instead line formation and zones of use as forms of social organisation, situating learning effects and turn-taking, where it is felt that displays should do more to account for these organisations (Müller et al., 2012) in supporting boundary creation and negotiation between users relative to content delivery.

A requirement for a system to be more "actively" or "socially" aware of how performative elements are likely to affect the wider ecology present a clear need to further explore the design space. While social organisation leads to formations of use, it is use which drives these factors, and so must be carefully considered in design and implementation of systems. Where structured content will define physical parameters to enable performative interaction, leading to a relative social organisation, any system-led content change will fundamentally impact upon an established status quo and should be addressed.

As a part of turn-taking and learning spectators will consider those who are engaged in on-going interactions acting as "performers", with the scenarios of awareness and approach the user can be considered to be in three states simultaneously as; The user acting as performer and spectator to their own impact through understanding of actions and control, understanding their relationship to the system and situation of the interaction, and actions performed for bystanders (Dalsgaard & Hansen, 2008). This links the concepts of performance, interaction design and l social organisation to situated content, where the affordances of presentation and layout will directly impact the relative social boundaries through a requirement for performative elements, "territoriality" and "ownership", and social organisation and formation in "learning" and "turn-taking".

As social organisations are the first step towards interaction in multi-user scenarios, barriers must be considered in design as well as maintaining suspense after learning but during use. Where we consider design for the spectator experience, there are four distinct relationships identified for spectator-content and performer elements; secretive - mostly hidden, expressive - easy for the spectator to identify, magical – changes can be seen but there is no clear relationship, suspenseful – effects are only revealed as the spectator takes their turn (Reeves et al., 2005). With multi-user systems we must consider the relation of elements of design to how interactions are observed and the role of presentation and layout in influencing boundary formations and interactions, as well as how users might then cross these boundaries in turn-taking and engagement.

Where distributed users can be considered to be "performers" and spectators through awareness of distanced interactions (Benford, S. 2010), feedthrough effects of performance in crowded scenarios gives rise to considerations of influence to interactions and the levels of control and feedback situated in interactive and adaptive systems. This relates not only approach and awareness with exploration of interaction, but fundamental design for shared, socially co-ordinated digital interactions. This requires wider interpretation of locus of control and points of interaction and entry, given the influence of organisation for single points of interaction, but also the capabilities of layouts to adapt and match the needs of use where multiple points of interaction may be available and acting to influence one another.

This becomes prominent when considering large displays and content, with increase in awareness and related glance behaviour from passers-by (Tan & Czerwinski, 2003). This is mitigated through presentation, with scale of presentation being a direct factor of perception, such as the Personal Computing paradigm, requiring entering the personal space of the users to engage (Brudy et al., 2014). Considering multiple user feedback across a single large display provides varying degrees of mutual awareness and acts to engage social protocol to regulate behaviours and negotiate actions. Limitations arise in how both parties might interpret display changes relative to themselves, however, there are still multiple unknowns in how multiple areas of user focus and control might interact across a single large display and the role this has in spectator behaviour or organisation.

Where changes in presentation can mitigate unwanted interactions between multiple users, (Brudy et al., 2014), it is significantly more engaging where layout adaptation work to support co-orientated groups within their interaction (Schiavo et al., 2013). With the current level of algorithm to interpret group interests being limited, the argument for group preferences in presentation, layouts and adaptation amongst familiar users is shown to directly relate to the interpretation of experience (Kurdyukova et al., 2011). This leads to considerations of interpreted adaptations relative to groups and on-going behaviours as a direct mechanism to both support and manage positive and negative effects in interaction, and gives rise to considerations of how relatively structured or scaffolded content will influence experience where there is an external driving factor due to social impact.

As multiple forms of social organisation are centred about points of interaction, either in direct use or exploration, there is a clear need to consider how this may affect the on-going experiences of all users. With boundary formation to facilitate interaction, secondary factors leading to spatial behaviours will impact upon experience and should be considered as a component of the interaction design. As digital displays are capable of changing their layout, it should be considered how changes may work to mitigate unwanted factors and provide alternative channels in better supporting wider engagement through interpretation of use and relative social organisation. This gives rise to indications that multiple forms of interaction with different type of content adaptation can be identified based upon the adaptations need or intent, but also wider factors of the interplay of multiple points of interaction which stem from this understanding.

2.2.5 Proxemics, F-Formations, Shareability

In finally identifying and expanding the nature of shared space we are able to consider how a wide range of factors of spatial behaviour, organisation, interaction and system response are inter-related in formations around displays. This relates considerations of co-orientated focussed interactions to describe these objects as mechanisms for further investigation.

In shared interactions we must consider layout, configuration of users, and nature of the on-going interaction as component of both the social and physical space during entry and approach. Between these factors users identify points of interaction and minimal barriers to engagement, so achieving shareability (Hornecker et al., 2007). As this expands in to group interactions, particularly playful one, we see awareness and gesture in groups increase, with around 21% of users identifying the need to leave space for others, and concluding actions where a user is about to leave (Coutrix, et al., 2011).

When we expand multi-user interaction to consider multiple groups we see up to 20 formations of users at large displays, where mobile entry points can initiate forms of mutual engagement as a dynamic interaction process, with individuals able to maintain interactions without losing individual control. Between these dynamic factors there is the need for territoriality and parallel interaction to either be defined by the system or in support of on-going use (Jacucci, et al., 2010). As a mechanism to define these formations and areas of interaction, we can consider the F-formations concepts (Kendon, A. 2010) to spatially orientate groups relative to a display layout.

Where layouts influence formations, with features of space prohibiting optimal organisations for the sake of social organisations, framing or boundaries of objects gives rise to alternative interpretation of group organisation, where “boundary objects” which have “enough plasticity to adapt to local needs of parties sharing them to provide boundaries, but also robust enough to maintain a common individual identity across these sites”, suggests that clearly demarked objects provide sufficient evidence of an isolated interaction in parallel with the formations around them (Star, S. L. 1998). It can also be that shared understanding of the interaction and focal object can encourage organisation (Marshall et al., 2011), suggesting sub-groups of experienced users may be identifiable through the manner of their organisation relative to a given layout.

While physical framing provides boundaries in spatial organisation there is ambiguity in interaction boundaries, especially spatially de-coupled interactions at very large content or multiple points of interaction. If we consider formations, particularly closed in nature, as a boundary condition there is scope for an interpretation of social interaction as a cue towards interaction and layout design. In describing boundary effects Greenberg (Greenberg, S. 2011) proposes the "Proxemics" framework as a mechanism to define interaction through socio-spatial boundaries with fixed and semi-fixed objects. This introduces a sociological element for digital artefacts to be considered in the same manner as other users in the space, where the 3-dimensional "personal space" of a formation boundary of an individual or group is transposed on to the 2-dimensioanl bounds of a digital object.

This was expanded to critical design challenges of spatial behaviours and interaction of users and object, revealing; interaction possibilities, affordance of actions directed to them, establishing a connection, system-response feedback, preventing and correcting mistakes, managing privacy and security. This presents opportunities and challenges in finding meaning through interaction behaviours, but also in designing interactions for multiple users in a perceived digital-social space (Marquardt & Greenberg, 2012). The key to maintaining balance is found through distance, orientation or eye-contact, where all can be altered as part of a "Dynamic Boundary Regulation Process" (Donald Norman, 1998 The Psychology of Everyday Things), however, questions remain around the role of display adaptation in supporting digital-social negotiation in multiple user, and multiple point of interaction scenarios, and the ways in which these forms of interaction management and mitigation might scale in order of complexity.

By identifying F-formations a supporting system could indicate points of interaction and highlight activities to temporarily break social organisations, suggesting that digital engagements, while acting in the same manner as human interaction, adopt different social rules and territoriality where users interpret a need. Here the interactions were device centric and there is a lack of understanding in how people relate to and between objects during multi user interactions (Marquardt et al., 2012), but this does present a clear opportunity to explore the role and nature of system-led adaptation in response to on-going and known organisations, configurations, and formations of use.

Emotional states portrayed through proxemics to digital avatars leads to social structures playing a large role in decision making in digital environments, particularly the effects of open and closed formations in joining behaviours (Rehm et al., 2005). This points to ideas of users interpreting relationships of layouts to social structures, such that awareness may convey more than interaction, with vested interactional states such as functional, communicative or emotional relationships between objects and user groups, and changes in layout highlighting junctures in social organisation, formation or use case being inferred from digital proxemics relationships. While this work drew on much richer contextual content featuring avatars, the spectrum of the underlying mechanisms of social-digital organisational relationships is still not well explored or understood and would form the basis of any investigation in to managed content at points of interaction for a system-led approach to spatial organisation.

2.2.6 Summary

Points of interaction form the focus for user engagement at digital displays, either through direct awareness or the social structures and organisations which form about them. The forms of interaction and behaviour seen are related to the actions and behaviours of each individual user relative to their state or level of engagement with the display and those in the space, acting as both spectator and performer to form the ecology of interaction relative to the layout and presentation of content.

Changes in layout are shown to influence and inform social organisations and spatial behaviours by providing feedthrough and feedback mechanisms via a digital-social relationship, which can both provide contextual information and drive user response due to adaptation in mitigating or influencing manners. The limitation in the current use of these systems is found in the relationship of interpretations of on-going social organisations, formations, and behaviours to display adaptation for multiple user scenarios, where adaptations have been prescribed but not considered in relation to informed or applied responses to given or known contextual use.

Where aspects of the digital-social relationships between users have been described for single points of interaction, there is the opportunity to explore how multi-users scenarios will influence and inform between users through content presentation and layout, leading to wider social organisation and use behaviours for multiple points of interaction. This can be contextualised during on-going use at a display, but should also be considered in the wider scope of the ecology of engagement, stemming from entry, awareness, approach, and interaction to consider the role of content presentation and layout in social organisations and boundary formation and transition in multiple parallel engagements behaviours.

As entry and grouping behaviours are not well understood in relation to content design and presentation this defines an initial area of investigation required to establish underlying factors of content and emergent behaviours in multi-user scenarios, before applying this knowledge to more complex multi-points of interaction use cases.

2.3 Nature of Digital Technology

In considering how digital technologies are presented in public settings there are a range of factors to address around the technology and forms of engagement with content. This must consider how the object draws attention through its situation, the nature of attraction and social use, and the formation of experience through interaction. This section will now consider; Forms of digital technologies for presentation, sensors employed to drive engagement and interactivity, the role of interactivity on physical and social space, models of engagement relative to displays, human awareness for cognition and the interpretation of experiences and concepts of experiential narrative. This will explore how displays can act as centres of orientation for public use, but also how the diverse interactions of multiple users can inform and influence the experience.

2.3.1 Forms of display technology

While there are a significant range of digital display formats, including; table top, handheld, personal computing, ambient screen, digital advertising, etc., this investigation is focussed on the role of very large interactive digital displays and their influence. As such we will briefly consider the fundamental factors of what constitutes the nature of these objects.

The inherent scale and situation of a display is seen to determine the nature of its potential use, with zones of usage being formed through available interaction (Fischer & Hornecker, 2012). There are considerations for presentation, but also the relationship between multiple displays in influencing awareness and interaction (Ten Koppel et al., 2012). This directly impacts upon the visibility of factors of a display, with components of relative user position and scale defining how and where a user may be able to see factors of the display (Xie, et al., 2007).

The situation and contextual nature of a display is critical in how it is interpreted and interacted with, where closed spaces and knowledge from the intended or expected user base will alter expectations around interaction and content. Semi-public displays offer grounds for multiple simultaneous use, but require a shared understanding of behaviour (Huang & Mynatt, 2003) for minimal barriers to use to support this. As part of the assumption of use, virtual content influences interpretation of spatial behaviours, where a virtual component can constitute a form of navigation or requirement (Benford et al., 1994) leading to negotiation between users.

Interactive and adaptive displays emphasise interaction design and flow of engagement to pull user attention, either through direct mappings of user behaviours or identities through the presentation of engaging content or interactions, or the social influence and organisations they engender (Müller et al., 2012). These forms of attention need to be context specific and hold an appeal to the target users, where generic content in public or ineffective content for a display medium sees significant breakaway from the intended interaction and suffers from an underlying "display blindness" (Müller, et al., 2009), leaving adaptation superfluous to any but the most engaged user.

Display selection must conform to the nature of use, with interactivity and responsiveness requiring sufficient real-estate and viewing arrangements to be effective. This must account for the full interaction design and processes of engagement available to users, with any limitations influencing the validity. Where we consider displays formed around direct interaction (Shoemaker & Booth, Whole-Body Interactions For Very Large Wall Displays, 2008), or as a spatial relationship in presentation (Marquardt & Greenberg, 2012), there is a need for the display to be fit for purpose in regards the wider space in its role as a focal point for both direct and spectated interaction, as well as an attractor in entry and awareness.

2.3.2 Forms of sensing technology

Sensing technologies allow for not only a general awareness of user behaviours, but fine grained interactions through spatial behaviours and direct manipulation. With support from software solutions it is possible to see proxemic and organisational relationship to objects as a driving mechanism in interaction and adaptation. Considering the nature of interaction, the effectiveness of any solution will require the selection of appropriate sensing technology to ensure accuracy in mapping scales of entry, social organisation, and approach behaviours.

From the earliest use of sensors in behaviour critical systems the onus has been on accuracy in detection and identification. High intensity scenarios addressing autonomous vehicles and identification of pedestrian actions identified the necessity for a sensor fusion approach (Scheunert et al., 2004). This approach ensures the correct conclusion are being drawn and offer robustness in the interaction but at the cost of sensors and development time.

With the development of sensor technology for fidelity the need for sensor fusion techniques becomes less pressing, with only specific interaction scenarios requiring multiple data streams. A taxonomic review of indoor positioning systems (Al Nuaimi & Kamel, 2011), highlights a wide range of technological approaches, however, the significant issue in assuring accuracy and maintaining data is found in the need for bodily worn sensors. This is limits use outside of laboratory studies and would not support a "walk up and use" application.

Consistent tracking approaches utilising ultrasonic sensors offer high degrees of fidelity and persistent tracking due to high frequency sampling (Wan & Paul, 2010), however, reduced range and required numbers for large spaces limits their use. Wider reaching passive sensing through analysis of changing states in Wi-fi signals identify “flocks” or clusters to establish the number and density of groups (Kjærgaard et al., 2012), unfortunately fidelity is lacking and this approach is better suited to identify general movement patterns across building scale spaces.

Between room and building scale the use of low level laser scanners supports high fidelity and persistent tracking with extremely high data sampling rate and significant reductions in occlusion issues between users (Zhao & Shibasaki, 2005). Tracking at ankle height offers an additional benefit of gait estimation to produce consistent identification and behavioural modelling through the Ballistic walking model (Mochon & McMahon, 1980). The use of this system is, however, limited due to the lack of bodily tracking and head or gesture interpretation.

More recently, the most effective solutions to room scale multi-user tracking has been through multiple camera solutions. This approach provides a light weight solution for multi-user tracking, reduced occlusion, and identification of position, orientation and proxemics interactions (Zabulis, et al., 2013). This solution was applied to the interaction with a digital display to drive adaptation of the layout, however, limitations in the interaction design did not yield significant insight in to the nature of multi-user interactions.

Camera based systems can support body pose estimation through time variant patterns of motion to convey meaning and emotional state (Schrammel et al., 2010). A relation is also found between Motion, Emotion, Interaction and Experience in determining affect, suggesting feedthrough effects where a relationship is formed between users and displays. Group-wise sensing has enabled detection of organisation and F-formations by process of graph edge detection (Hung & Kröse, 2011) and improvements in body pose estimation for interpretation (Shotton, et al., 2013). Combined, this provides individual behaviours and affected states in combination with formation to generate and interpret group interactions with content.

Extension of matching techniques also support Head pose estimation (Riener & Sippl, 2014), although the estimations are found to be very course when assessing fine grained interpretations of displays. This technique is somewhat improved with gaze estimation (Correa) to offer an interpretation of vision, however, this is a complex problem space as the variability of user behaviours is very broad when considering generic sensing solutions.

The most impressive developments in sensing in recent years have been found in the Kinect camera suite, offering both RGB and Infra-Red depth images. The technology is supported as off the shelf, although there are limited solutions for multi-camera arrangement. Work to provide body pose estimation (Schwarz et al., 2012), combined with head pose and gestural interaction, would aid in offering a powerful supporting body of software.

In all a balance must be struck between the requirements for accurate data capture and time taken in development. These requirements must be considered through an observation of natural interaction with digital systems and the limitations in granularity of data capture.

2.3.3 Roles of interactivity

In considering how technology can support engagement it is also important to address the role of interactivity in shaping spatial behaviour. This is described across multiple forms of interactive and adaptive systems.

As experience is based around awareness and actions we must assess the stages available in forming interpretation to describe interaction. Building from Garzotto's (Garzotto & Rizzo, 2007) assessment of forming interactions, we find the significant conditions are: Usability, Interaction model, Expanding experience, Social interaction, and Contextual affordance. This builds a basis for how varying factors of spatial awareness and engagement influence interaction, and places user behaviours in a context to interpret their impact.

With spaces open to interpretation the inclusion of ambient displays influences movement and decision making, with emphasis towards content shown (Varoudis, T. 2011). Distanced interaction influences movement in a two-fold role, with immediate transmission of information leading to changes in behaviour, but also the introduction of an affected state posing a point of interest or contention to others. Where systems can gain attention and cause impact, content and interaction must support the original use of the space to avoid become an issue (Sawhney et al., 2001). If an interaction requires additional feedback to convey its meaning then the role of interaction will separate groups of users, where the role of social displays is to support coordination, negotiation and a sense of belonging.

While a system can alter presentation to ensure readability for a single user the impact to the wider space is found where external users are no longer able to engage in a similar manner (Sukale, Koval, & Voida, 2014). This shifts from flexible boundaries of interaction for passers-by (Brudy et al., 2014), in to the context of on-going use. While sharing and negotiation still take place between multiple users for optimal organisation, this issue is compounded where systems are tied to interpretations of individual behaviour or affected state (Wang et al., 2012). Unless the design of states aims to incorporate shared interactions, the delivery of content will have a two part impact, by either portraying user state, such as emotion (Tan et al., 2013), or creating a separation in interpretation for other users, placing focus on the user.

The use of "shadowing" or "mirroring" the users form on the display is found to be the most effective in both drawing attention and gaining interaction, "closing the loop" between action and reaction, supporting learning and investigation (Shoemaker & Booth, Whole-Body Interactions For Very Large Wall Displays, 2008). These forms of interaction also projects the nature of the interaction out, drawing attention to support "Honey Pots" as well as learning effects through observation. The use of shadows or projections of direct mapping supports a mechanism for coordination during interaction (Shoemaker et al., 2010). This coordination acts as an indirect source of feedback about actions of those in the space, using the display for factors such as relative position and orientation, and can be seen to support depth-corrected interaction behaviour between non-situated users to encourage play (Ledo et al., 2013). Forms of shared experience and in particular playful interactions are seen to attract attention, so strengthening interpretations and engagement with the interaction.

In forming an experience the flow of information and user control must be presented such that understanding can be found, but also falling within expectations for the context of the place and nature of the experience. In exploring interactions across macro-environments there are questions around content either being pulled or pushed by the user or system and the role this plays in forming experience. With forms of complex “learning environments”, it is important to allow users to rest during interactions to reflect on the interpretation and at the same time users may want time to interact with others without digital interference (Bedwell & Koleva, 2007), where ultimately excessive influence may act to diminish the experience.

As part of this a key design consideration must be the spectators and the manner in which they form an interpretation in gaining their own experience. Reeves, et al. (Reeves et al., 2005) present four relationships of the user-content, performer-spectator roles during interaction, where the design of the interaction may be; secretive - mostly hidden from the spectators, expressive - easy for the spectator to identify, suspenseful – effects are only revealed as the spectator takes their turn, magical – changes can be seen but there is no clear relationship.

As spectators can also become performers, barriers to interaction must be considered in design but also in maintaining suspense after learning but during use. This is best described in exploration of interaction, where it is suggested that the discoverability of hidden information by user-controlled exploration causes the user to engage more deeply with their discoveries (Izadi, et al., 2002). This places emphasis in the design for spectators, but also on-going user interactions in the case of simultaneous users. Where we have considered how feedthrough based in interactivity and manipulation can aid in coordination and negation, it may also be that components of interaction become apparent, so mitigating the potential experience. This raises questions around how structured content can prescribes organisation and learning, but more importantly, how considered adaptation can form timely interventions within the learning processes of spectator engagement.

In co-located groups, or constellations of use, interactions may not always be optimal in either interaction design or the use of space. Real time layout changes to influence constellations show movement of points of interaction to be an effective mechanism in altering distribution and use, however, this comes at a social cost by inducing social pressure to support interaction (Beyer et al., 2014). Where mirroring is seen to be effective in drawing attention, moving content has a reduced impact as the relationships are hard to draw when presented as an ambient effect. Instead presenting the interaction as a static object proves more effective, unless offering some additional form of feedback.

Allowing for group members to have autonomy within an interaction gives a sense of ownership while building a shared interpretation and experience and leads to richer, more playful interactions (Coutrix, et al., 2011). As group interaction is shown to lead to the best forms of experience, these forms of interaction will present an impact to the wider ecology. Where other factors consider how interaction can influence behaviour or interpretation, the concept of actively encouraging groupings of users’ leads directly to experience, but raises questions around relative and on-going behaviours.

While these findings suggest that single displays, potentially offering several points of simultaneous interaction, are most effective in developing the user experience, this does not account for the negative connotations of social boundary impacts involved in gaining an interaction. For a user maintaining a fixed point of interaction the stages of awareness, approach, learning and engagement are more clearly defined, however, the aspects of “Honey Pots”, “Shoulder Surfing” and crossing social boundaries is not considered or related to content delivery as inherent factors around a static point and needs to be further explored.

Where a digital display may be able to adapt its layout in mitigating these factors, instead users are left to "deal" with evolving social organisation either through cooperation, competition or negotiation between boundaries as the engagement forms. This offers an avenue of investigation for how these factors arise about multiple points of interaction and where overlap occurs between the influences of display use in entry, awareness, and approach in the formation of parallel engagement.

In these cases factors of display layout and presentation have been utilised to "guess" at the impact of changes to user interaction in exploring the role of the display within the wider space, where these investigations can help to inform the design space but do not fully explore the potential or role of displays. Instead these studies indicate towards the utility of adaptive content as an ecological entity providing feedback and feedthrough within the formation of experience and interaction of all users. In further exploring the role of content adaptation, a "best guess" scenario lends itself well to an iterative investigation in clearly relating specific factors of display use to emergent forms of use.

2.3.4 Engagement (models of)

Where a single user in isolation may identify the interactivity of a display and respond, the inclusion of other people, even as the initial identifying factor to interaction (Honey Pot), will greatly influence how and where an interaction may then take place, altering the nature of engagement. To describe how engagements may be modelled, the stages need to be considered, with; awareness, honey pots, landing, row formation, learning, spectating, approach, and engagement to name several (Müller et al., 2012). These describe the bulk of behaviours seen in forming an engagement with a digital display, but do not begin to answer the question of how this can be framed and supported.

Transition from an implicit to an explicit interaction, namely moving from an unaware and public state to a focussed personal interaction, identifies four fluid inter-phase transitions: ambient display, implicit interaction, subtle interaction, personal interaction (Vogel & Balakrishnan, 2004). While this separates out actions and behaviours in to components of engagement, there is little to describe how any behaviour may be classified either socially or spatially, being open to interpretation and rapid shifts between states given environmental impacts.

By expanding ideas of internal users states, such as user, performer, spectator, we can refine what actions and interactions mean in the scheme of engagement phases, where a user can be excluded from states given a known relation to others in the space (Dalsgaard & Hansen, 2008). This indicates the potential scope for framing by reduction, but does not support direct interpretation of engagement or potential for interaction outside of very specific behaviours, such as territoriality, turn-taking or approach. In the case of performer-spectator, we can ascribe a wide range of "roles" to these states, with certain actions engendering response as well as conveying information about behaviour and intent (Peltonen, et al., 2008). These considerations are able to account for factors of affordances, performative elements in learning and in negotiation to describe a richer set of interactions in achieving engagement.

An issues appears with approaches which are attempting to qualify specific aspects of an engagement, as it is not clear if the result of the interactions in shared space are supportive of satisfaction or understanding (Kämäräinen & Saariluoma, 2009). While a lack of satisfaction or understanding may result in leaving these factors should be address in design. Instead, interpretation of these factors through engagement behaviours can act to inform how and why users may transition in and out or across phases or states in ways these models struggle to identify. This can be seen where actions and interactions become embodied, so leaving the user separated from a range of potential engagement protocols and potentially passing through a range of state or phases without being aware (Benyon et al., 2010).

Perhaps a more comprehensive approach is to consider the overarching phases of engagement across a range of display and interaction types, with; awareness, movement and interaction incorporating social and performative elements to describe inter-user organisation and relationship (Müller et al., 2010). This shifts attention towards behaviours to infer motivation in crossing a boundary, allowing further separation of specific states to support actions which may not engender a high level phase change, but instead supports a localised interpretation of understanding or satisfaction, however, this is based in extremely fine grained observation and difficult to tease out.

Within each of these models of engagement there are inherent issues with forming an interpretation of the system, on-going use, social interactions and inter-relationship. Furthermore, there is very little done to resolve spatial behaviours in to these models, although the situation of a display and the impact on spatial behaviours and potential use has previously been described (Fischer & Hornecker, 2012). It seems a fundamental consideration of how space can be used relative to a display and interaction may shed further light on how social interactions and performer-spectator roles can fully develop before levels of interpretation are applied to describe the more subtle transitional aspects of engagement.

Considering a taxonomic review of these approaches, it is felt that the need for a context aware ubiquitous system to present a subjective model of engagement, found through an iterative process of evaluating interactions would be appropriate (Kühn et al., 2011), as this would begin to separate out the low level components of individual organisation to the higher level emergent behaviours which result in boundary formation and the need for user negotiation.

As there is currently little understanding around how entry and awareness of content layouts and adaptation lead to formations of users, there are considerations of how natural organisations come about relative to varying forms of content presentation which need to be better understood. By considering an iterative approach in investigating how emergent forms of organisation come about relative to reported behaviours and the models of engagement, a retro-active understanding of the role of content and adaptation can be established.

2.3.5 Theory of Awareness and Cognition

The interpretation of social and physical behaviours in space is seen to be formed out of the nature of the social lenses of behaviour and interaction, as underlying mechanisms of awareness and interpretation form the basis of how changes in the environment affect real time behaviours. As a part of the awareness of ambient and interactive changes to the environment, the processes of interpretation offer insight in to the manner of response, and describe the likely response behaviour to given actions and reactions of a display.

Where users are required to share an interaction space we see territoriality and guarded interaction around knowledge and resource sharing based in the physicality of display real-estate (Peltonen, et al., 2008), formed through subjective desires for individual control. Where task based problems are considered, we find that collaboration and organisation of information across space leads to more effective outcomes, with negotiations focussed around the locus of interaction, and a wider sense of interpretation found in physical gestures and workflow between multiple objects as an out of band organisation (Bradel et al., 2013).

Where physical and digital space blend there is seen to be an inter-relationship of changing factors of layout and interaction, where “anchor points”, or specified points of engagement seek to bring the two together. While there is volatility in both forms of behaviour, digital behaviours are able to subvert pre-conceptions and understanding of users, so presenting both informative and irritating engagements (Benyon, D. 2012), so presenting a need for digital content to be more physically and socially context aware to user behaviours and organisations.

Where a user may be situated in an environment through factors of the space, such as; display presentation, on-going use and social organisation, multiple facets of user-content relationships, etc., changes to layouts and interactions are able to influence factors of the environment without apparent meaning or warning, leading to a breakdown in interpretation and separation in the process of engagement. This fundamental issue of action and reaction describes a significant problem space in interpretation around digital systems (Dix, A. 1994), where interpretation of awareness and interaction are not accounted for in the design and application of changes to layouts.

As a part of wider awareness, we can consider physical limitations in vision but also system based interpretation of awareness. Where we might consider head pose estimation as a mechanism to identify focus, there is an inherent spread in response, with a 30 degree range of motion in awareness response, but also a +/- 30 degree deviation seen across the population. Where it is seen that there are head-movers and there are non-head-movers (Stahl, J. S. 1999). The range of response is stressed further in dynamic action, where users may exhibit up to 55 degrees of eye movement during a 60 degree rotation between points of focus, where the eyes are not centred in the orbit (Freedman, E. G. 2008). This physiological limitation lends significant weight to the consideration of design and the role of peripheral and focal awareness towards changes in layout, which suggests that adaptation, no matter the form, must be visible and comprehensible to the intended users.

Where automatic changes to layouts and interactions take place outside of a locus of awareness we find users feeling a loss of control, where frustration and insecurity in the interaction may lead to abandonment. It follows that adaptive ubiquitous systems should make changes transparent, controllable and trustworthy to be effective in maintaining engagement, but also in the wider sense of an interaction focal point (Kurdyukova, E. 2011). This introduces an interesting consideration of how unobtrusive out-of-band content changes may be utilised in the framing of spectator awareness and interaction.

In relating a sense of physical awareness to cognitive processing of stimuli, Demiris (Demiris, Y. 2007) present a mechanism to help draw intent from action in the same manner as human cognition. Utilising pairs of interpretive models of actions and behaviours, the real time action can be compared with the expected, or modelled action to rapidly fine-tune a sense of the world. Where this approach is then coupled with a response behaviour, a number of classification-response pairings can be made and interpolated with respect to set of action (Sarabia et al., 2011). Where the classification of the action can identify a pairing, the interpolation of the response leads to an insight of the outcome, so allowing new forms of model pairs to be created to assess fine grained actions before they have taken place. This leads to an extremely fast and highly accurate computational representation of the world state and actions in it.

2.3.6 Trajectories

As a part of forming experience, in a similar manner to forming cognition, there are a series of interpretations which are made about an object or interaction which define our expectations of its nature and how our experience with it may form. While changes in these expectations can lead to positive or negative interpretations, it is important to consider how and why this may be the case. Theoretical models of user and experiential trajectories describe how arcs of action and intention interweave to identify points of transition or separation between the potential forms of an interaction.

The issue of trajectories in interaction is that it is not always clear what the effects of factors of space, design or social interaction may be within a dynamic engagement. Where a design may be perfectly effective in drawing attention or conveying intent to the user, the timing and awareness to these factors can be immediately lost or conveyed incorrectly through external influences or interpretations (Dix, A. 1994).

Benford, et al. (Benford et al., 2009), present the trajectories framework to describe stages of interaction and points of varying experiential or external factors in influencing the nature of a designed experience. This considers how an experience might account for variability within a situated context, with junctures across the same aspects of a single trajectory allowing for multiple version of the same experience to be run in parallel, with deviations in one acting to inform or influence the same considerations in another experience.

An example of a single user interaction within a trajectory has shown that presenting an adaptive layout based on influences in the models of interaction can lead to high variability in the nature of interpretation of the system (Limanto & Lee, 2013). This suggests that while a model of interaction behaviour can support direct interaction, the interplay of defining factors within the model can alter how this unfolds relative to external factors or changes in the desired outcome of interpretation. Instead these changes become most effective where we look to consider engagement “flow” within an interaction (Gilroy et al., 2009). If we consider that a model can either imply direct changes as the result of design to encourage a form of engagement, a trajectories based approach offers a more fine grained solution to interpret actions, reactions and the state of the engagement.

In identifying barriers to approach and engagement it is possible to account for deviations from the optimal user trajectory. By assessing the models of awareness and forms of interpretation relating these factors to approach in real time, interactions can account for forms of deviation to provide correcting actions (Cheung, V. 2016). This now leads us to consider how wide spanning interpretations of trajectories can be coupled to account for multiple users while addressing the issues of interactive or adaptive systems, where we find large numbers of potential outcomes and an equally large number of forms of interpretation.

2.3.7 Summary

Multiple forms of engagement and interactivity have been considered around digital displays in attempting to address how users pass through stages of awareness and engagement. These consider how other users in the space will influence the process, either through physical presence or by the nature of their interactions, however, there is a consistent focus of these investigation towards static layouts, where interactivity is considered at a single point and acts to draw attention and convey learning without addressing how multiple points of interaction may influence one another or project out in to the wider space.

Where these models can convey an interpretation of direct interaction or awareness and approach, any separation of user intention at any phases of engagement must be handled by the user, either through negotiation, cooperation or competition for space and the interaction, with the result being either a shared experience for better or worse, or in abandoning the initial intention for engagement. It can be seen that multiple points of interaction are possible given the nature of the technology, but there is a need to consider how these may interact and the outcomes or requirements of the experience. Any application of multiple points of interaction should address the particulars of the individual interaction as well as the interplay between them to frame and support multiple use.

While the varying models of interaction describe how states and phases of engagement may fluctuate, and the mechanisms by which this can happen between one another for any given user, there is a distinct limitation in a unified language to describe these in socio-spatial terms. This presents a disconnect between how a digital system might interpret low level physical, social , and engagement formations to present content, and also begin to identify internalised subjective transition in parallel trajectory formation. Instead the opportunity lies more in the area of reporting experience relative to quantifiable actions and behaviours to reverse engineer sentiment and meaning which can only be described by higher level thinking.

This presents the opportunity to explore and describe the relationship of content adaptation to on-going multi-user scenarios as a part of direct interaction, before then exploring these factors as a part of wider social organisation during entry, awareness, and approach. The role of adaptation is further explored in its impact as a prescribed tool in influencing these organisations and how these factors alter as additional points of interaction are considered across a wider display or interaction space.

2.4 Summary

The review of the literature has laid out a series of areas of discussion relating the underlying factors of an ecological model of spatial interactions around Public Large Interactive Displays (PLID’s) for Multiple Independent Simultaneous Users (MISU’s). This has considered the physical properties of spatial arrangements and how these may inform movement, including the presence of organisations of objects and affordance in interaction and decision making. These concepts have then been developed to address the situation and role of digital display technologies and the manners of engagement which are seen around them. This considers the influence of awareness and engagement across physical and social spaces, but also the role of interactivity and changing factors of the display layout to the wider space.

Building upon this the work then goes on to address how displays and points of interaction can act as focal points for social organisation, and how behaviours and use may inform and influence the space around them. This begins to relate the notions of display layouts and interactivity to influence in group and crowd behaviour. Considerations are then made for how interpretations of organisation and on-going use may be related to factors of system behaviour and engagement through awareness as part of the wider use of space, specifically in entry and approach behaviour to on-going use. This is then encapsulated within interpretations of interaction and engagement with interactive and adaptive systems to present the relative interactions between components of display behaviours and phenomena of physical and social space.

With this in mind, the final consideration is around justifications and mechanisms of evaluation, and design and development for these forms of systems. Throughout this review issues around the current levels of understanding of the role of content presentation and adaptation have been identified relative to their impact in on-going use and during entry and approach for multiple users. This has shown that there is a need for an initial exploration of how content presentation and layout influence, inform, and affect users behaviours relative to a display and indicates a need to iteratively explore these factors for multiple users and multiple points of interaction in more fully understanding the range of impacts which are present in these forms of systems. The points addressed here are now expanded through the thesis in exploration of the research question and objectives.

Chapter 3: Methodology

This chapter considers the overarching approach and specific methodologies applied in addressing the research question and objectives. The primary focus of this chapter is to describe the approach and justification for the methodologies applied in the data capture and analysis stages seen in each of the study chapters.

This body of work aims to address the following Research Question:

> **How can people's spatial behaviour be used to dynamically lay out content on multi-user, interactive screens, and how does this dynamic layout affect people's spatial behaviours?**

This will be done via a series of sensitising and iterative investigations within a wider framework of understanding which will now be presented.

Both Social Science and HCI are tightly coupled through the supporting Epistemological understanding presented in the Ecology Model (Heath et al., 2002), which describes the nature of social and physical phenomena of persons interacting with and around others when experiencing mixed-media installations. This high level conceptual model of experience accounts for multi-modalities of interaction, both within and between groups as well as between strangers, all as part of a simultaneous ecologically informed experience.

These phenomena are described in further detail by considering the specific interactions (Hall, et al., 1968) and formations (Kendon, A. 2010), etc. of those interactions to provide a specific knowledge basis in a variety of contexts. Refined models have then classically been applied to HCI investigations to inform and identify the relationship of social organisation to technological interaction and display, along with the emergent outcomes of these relationships i.e. Honey pots, spectators, leading, and learning effects, etc.. The scope of these studies within the role of display behaviour has, however, been limited to co-orientated lab-based investigations or established groups of individuals during "in-the-wild" investigations, so restricting the applicability of findings to true ecologies and public spaces.

This now presents a problem, where exploration of either social organisations or the role of technology does not constitute an "ecological" approach, instead describing relationships towards technology in a defined state. The resulting mismatch between the isolated scopes of understanding and general applicability to real world systems presents serious limitations in the relation of display concepts for interaction and the categories of use described. This leads us to consider the design and implementation of an investigation into these factors.

3.1 Research Design

The considerations of high- and low- level phenomena observed in varying forms of investigation highlights the issues of; generalizability, precision and realism, suggested by the "strategic dilemma" (McGrath, J. E. 1984). As the collection of evidence cannot perfectly account for these three factors, there is the need to consider the relationship of research methodologies and the applicability of the findings to the wider context.

As described in the "strategic dilemma", both in-the-wild and lab-based methodologies allow for research with HCI systems in different aspects, given the research question, implementation and robustness of the system, where each will offer altering potential in evaluating the system. As such, we must consider the trade-offs between both approaches;

- Realism – In-the-wild offers higher realism through observation of real users, where lab-based studies are subject to representative users. The use of scenarios and interaction design in lab-based studies can help support the realism and applicability of findings, but also introduces considerations of limiting or leading the results.
- Control – In-the-wild studies suffer due to varied and inconsistent repeatability in user behaviours but grants the potential for in-depth data capture through limited control. Whereas lab-based studies have strictly designed environments, user selection, and data collection approaches where the interpretation of user centred control becomes more relevant.
- Development – In-the-wild systems must be robust to support all use cases leading to limited scope for rapid emergent and novel functionality, compared with a rapid test bed for prototype and developmental systems in lab-based environments.

This is not to say that both methodologies are not applicable given the overall research approach and the intended outcomes described in each phase of the investigation. This thesis presents a combination of these methodologies to explore the nature of multi-user interactions in identifying where factors of control may be investigated in a real-to-life lab-based scenario. This is described below (Figure 3-1);

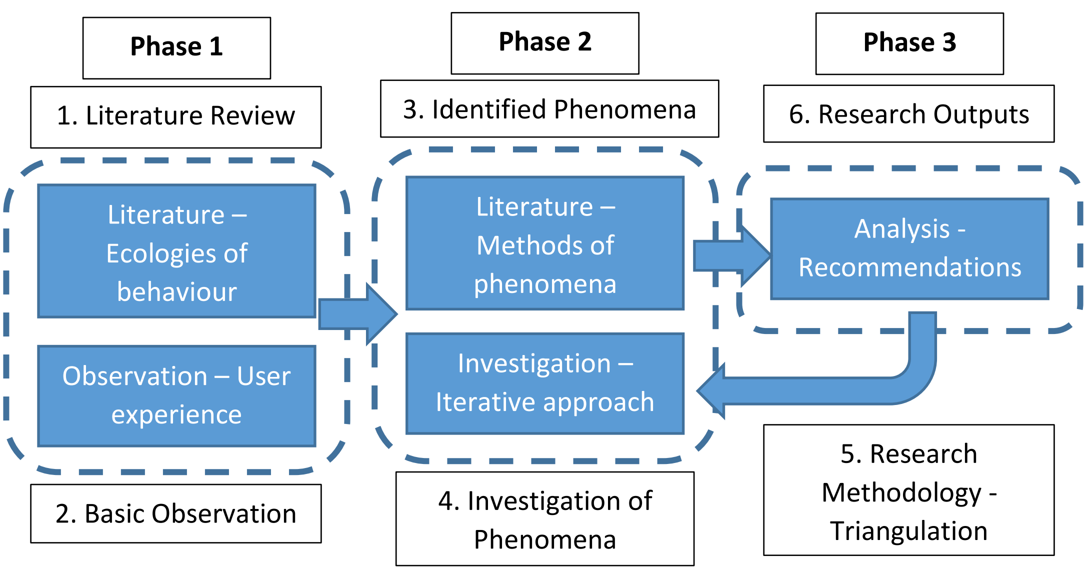


Figure 3-1: Identifying gaps in knowledge to inform an iterative investigation of unfolding interactions and emergent phenomena of multi-user interactions.

The above approach outlines three key areas in triangulating the problem space, identifying factors of the investigation and situating the results back to the context of understanding. In this sense, phenomena found in literature and lab-based observation are related via HCI methodologies in an exploratory design research approach to associate key areas of interest (described below), as a mechanism in scaffolding user interaction in relation to factors of display use and presentation. This mixed methods approach provides stronger inferences and offsets the weaknesses of any one area of investigation. The methodologies employed consider thematic analysis in identifying the critical areas in both behaviour and design to assess the overall function and influence of the interactive system, these methods are;

Field Work and Initial Observation: Observation aims to link the theories and prior understanding found in literature to in-situ scenarios of use and forms of natural behaviour. This acts as a sensitising exercise to evaluate how organisations of space, content presentation, and social interactions and behaviours evolve in exhibition spaces. Not only does this draw on prior knowledge and interpretations found in the literature, but seeks to identify the critical behaviours that emerge from these interactions, and so form the basis for an investigation. A number of museum and gallery locations were selected based on the size and layout, footfall, and the content and display types available.

Observations were carried out over several hours at each location, with the emphasis being on; the influence of the spatial layout in interaction, the role of spatial use, phenomena of social organisation, and mechanisms of interaction exhibited by users between each of the previous factors. This sought to find how and where displays may influence spaces, but also the changes in behaviour of users in achieving an interaction. The aim of this was to find relationships with elements of control within the content presentation which may affect the space, and so provide a number of entry points to the wider investigation. A number of data sources were used in this stage in trying to establish a broad understanding of the spaces as ecologies to further refine the potential interpretations of visitors.

Wizard-of-Oz: As a common practice in HCI investigations this method provides a test bed for investigation of theories and observations with display factors identified in the observation stage. Multiple factors of display presentation were replicated and controlled in relation to user behaviours to evaluate the impact. Two rounds of testing were carried out, with the first group selected from experienced HCI practitioners to elicit more in-depth considerations of the user experience, and the second from a general population. Observations, individual reporting and focus groups were used to triangulate the meaning and interpretation of multiple factors of the display presentation, with broad themes of; spatial, layout, observation and response behaviours being related to forms of the content shown. There were multiple rounds of testing and refining data, with the outcome being a series of design considerations to be assessed iteratively in refinement of how display and content could be used in managing and scaffolding user interactions.

Quasi-Experimental Iterative Laboratory Study: Drawing upon the understanding of methods of observation and system requirements from the "Wizard-of-Oz" study, the experimental design and implementation explored the influencing factors of display layout changes relative to the entry and engagement behaviours of users within the display space. The studies explored a number of content mappings to users' entry behaviour and investigated a number of design considerations for both responsive and system led layout changes, ultimately presenting design recommendations in answering the research question.

Users were selected from a demographics ranging from university students and academics to members of the public. Data captured included video of the interactions and audio of group interviews, including individual reporting and semi-structured group interviews. This was related to thematically codified video analysis and vignettes of identified behaviours in establishing distributions and critical factors and changes in behaviour. As the interactions were free-form there were many points identified, with only critical aspects presented in detail, with secondary considerations discussed and presented where appropriate.

These methodologies are applied within the phases of the approach as described above (Figure 3-1). Each of these phases employs several of the methodologies in differing manners to frame the research area and encompass aspects of user experience, presenting a broader picture of the interaction. The phases of the investigation and relative methodologies are;

Phase 1

Identify the high level ecological behaviour and low level descriptors of displays which are found in literature. This is followed by an observational study to consider where limitations in the combination and application of this knowledge to real world situations existed, and where there are factors of displays which influence or cause deviation from behaviours described in prior work. This will draw out any critical factors of either social or display behaviours to inform the next phase of the investigation, and is described by a two-step process:

1) Establishing a basis of understanding – Considering the current state of literature and the forms of spatial and interaction behaviours which take place around displays. This initially identifies the gap in knowledge but also presents a series of natural behaviours. Limitations in these findings exists between the ecological interaction of these factors and the development of interaction and content design outside of these considerations. These limitations provide the context for the gap in knowledge and the areas of investigation around the design and presentation of content and layouts for study.

2) Simple Observation – Sensitising and identifying the role of behaviour at real world installations to clarify the nature of display use, including; situation, content and interaction types, and the scope of mismatch between use as described and natural MISU interactions. Where there are points of conflict or changing behaviours identified in users and groups, this will provide an initial area of investigation for later study.

Phase 2

This phase builds upon the outcome of Phase 1, with factors of use considered within a number of structured interactions and a series of behaviours and themes identified around issues of natural use and influencing factors of displays. These are then used to more accurately describe components of natural use and the relationships held between user and display actions for further investigation, and is described by a two-step process:

3) Identifying Phenomena – A combined approach of addressing the outcomes of the simple observations to identify critical behaviours and themes in natural use related to prior literature. This will highlight the influencing factors in display use and changing layouts leading to natural organisation and phenomena of use, suggesting where there are underlying factors within multiple user interactions to inform an iterative investigation with a working system.

Each of the three studies with the working system assessed;

Responsive mapping: What are the themes in multiple user interactions when entering, exploring and understanding the space, and how key aspects of the display and user behaviour influence and inform changes in these behaviours. This considers the overall space, on-going use and changes in the layout or presentation in the interaction outcomes.

Adaptive layouts: Where and how did natural low-level phenomena of interaction form and what were the emergent behaviours of users based on feedback and learning in these scenarios. The main aim was to identify how natural organisation came about and how display changes could be applied and evaluated.

Predictive adaptation: Can adaptation be applied in an informed manner relative to identified entry behaviour where there is an understanding of emergent behaviours and natural organisations, and how effective is feedback in supporting on-going use.

4) Investigation of Phenomena – A consideration of system and investigation design derived from observed interactions and themes. This leads to a full investigation of critical behaviours to more fully understand the influence of display changes and user experience where multiple users interact around the same display. Through identification of themes and natural interaction behaviours a number of critical design factors can be identified in the design and implementation of an interactive system for more focussed assessment.

The outcome of this phases is to critically assess the nature of display use and influencing factors presented in literature but not fully situated in the context of "real world" MISU interactions. Identification of these aspects and their influence leads to a platform for a wide ranging investigation of influencing factors for informed system development.

In practice this is an iterative phase which builds upon the analysis of the findings at each successive iteration of testing (Figure 3-2), with the analysis step (Phase 3) following directly. Results of the analysis are filtered back in at the top of Phase 2, with each step repeated. The relevance of this process and specific application of methods is detailed in the subsequent chapters.

Phase 3

Analysis of behaviours and display parameters via triangulation to establish further themes and phenomena as a series of related design recommendations and outcomes. These outcomes are linked back to inform the iterative design and testing phase to identify where limitations in knowledge exist. These factors are then related to the influencing factors of display behaviour in identifying where components of display behaviours can be mapped to evolving and emergent user behaviours and phenomena of interaction.

The outcome of this phase is to present a series of design recommendations for user interaction and the effects of display factors across a variety of natural MISU interactions. Critically, the recommendations situate interaction and display factors within the wider observed behaviours of natural use to provide a richer knowledge of MISU interactions.

Each of the three main studies considered different sets of outcomes;

Responsive mapping: Which aspects of space and real-time layout influence natural organisation and low-level phenomena during entry, and how do changing aspects of layout inform and influence on-going behaviours. The aim was to identify emergent social organisation through learning and feedback based on changing aspects of the display layout.

Adaptive layouts: By considering on-going low-level phenomena and emergent organisations of users, combined with influencing factors of layout changes and feedback, how, where and when can changes to layouts influence and inform decision making in multiple user interactions and which may limit the applicability.

Predictive adaptation: By considering multiple forms of user behaviour in entry and response to on-going use and display changes, how effective are forms of feedback in supporting entry behaviours and user experience for informed predicted adaptations. This considers how accurately entry and approach can be predicted and supported by a display to facilitate greater utility while mitigating impact to on-going use. This aims to identify limitations and minimum design requirements in these approaches.

This phase is described by the analysis methodology, which presents a two-fold set of outcomes. The analysis methodology is described below;

5) Analysis for thematic phenomena – A process of thematic clustering and user experience feedback are triangulated to consider interaction with each form of the system, and to identify the role of these interactions in the overall use as factors of social influence and understanding display feedback. These outcomes lead directly to the second point described below, but are also critical in the iterative design process and system development.

6) Design recommendations – With each iteration of the system design the outcomes refine the problem space around aspects of on-going use by MISU's and indicate how low-level social organisation and phenomena develop in relation to the presentation of content. These outcomes are directly related to the overall design and testing phases of the investigations; Responsive, Adaptive and Predictive configurations, to define a series of themes and interaction behaviours. This presents best practices in design and user experience as their main findings to suggest how layout changes can be used in an informed manner.

The approach was to use individual structured or semi-structured group interviews to identify participants thought processes, as well as critical aspects of display and other user behaviours which influenced decision making. In the final iteration a vignette representation of video data is time coded to relate actions of the display and participant based on the themes identified. Finally, a quasi-quantified analysis was carried out to identify the rate of changing behaviours observed and the relationship of user reporting to these changes.

The quantification approach focussed on aggregated thematically coded data points to assess the significance of the range of inputs to the final outcome of the user interaction. These outcomes then describe the interaction and expand upon the contextual meaning. This was not conducted as a truly quantifiable study as there was no null hypothesis or stringent control of variables, however, analysis of the distribution helps to structure the user reporting across the varying changing factors of the space, painting a wider picture of user experience to interaction behaviours.

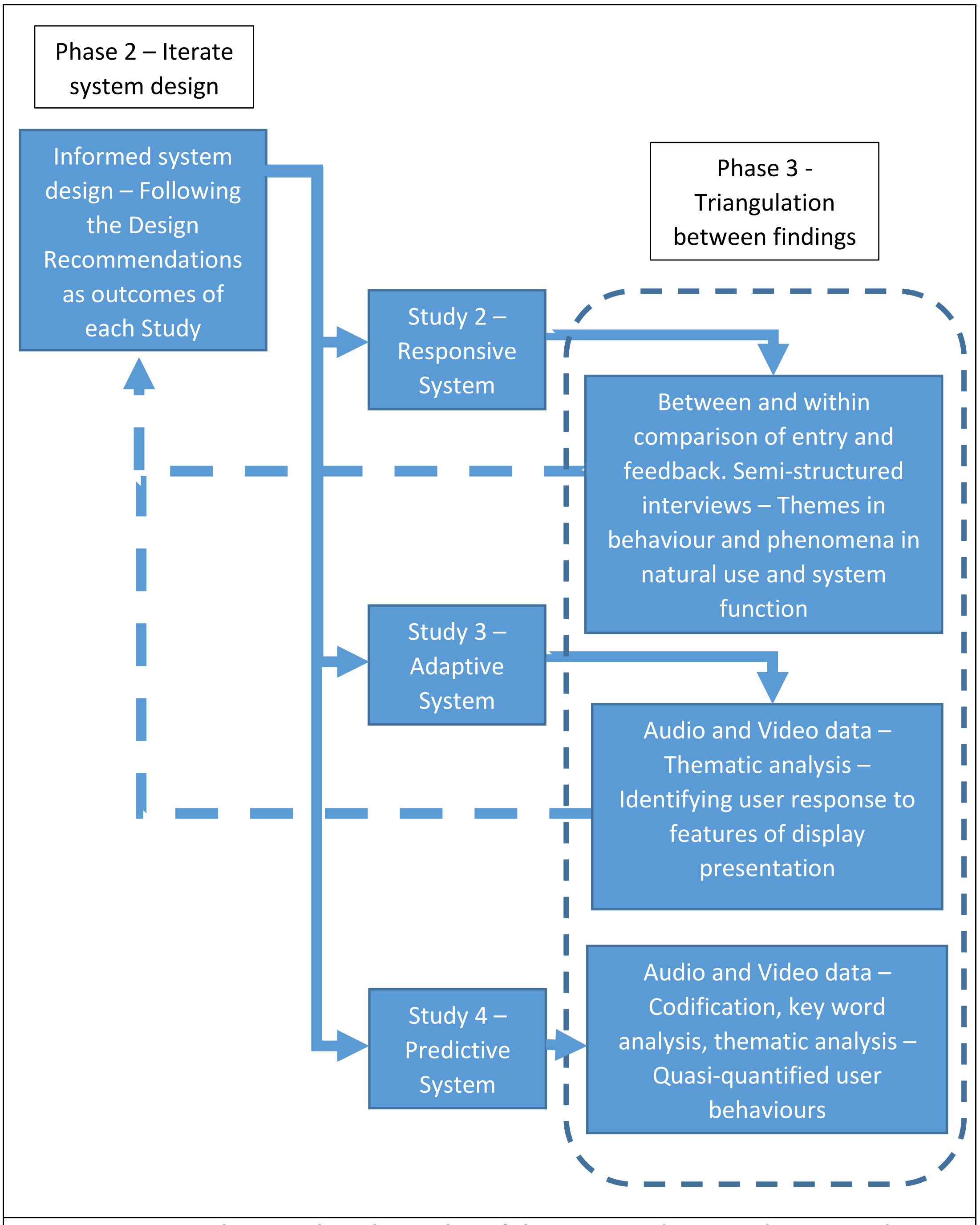


Figure 3-2: Showing the relationship of the iterative design and associated methodologies.

Phase 3 is described below (Figure 3-3);

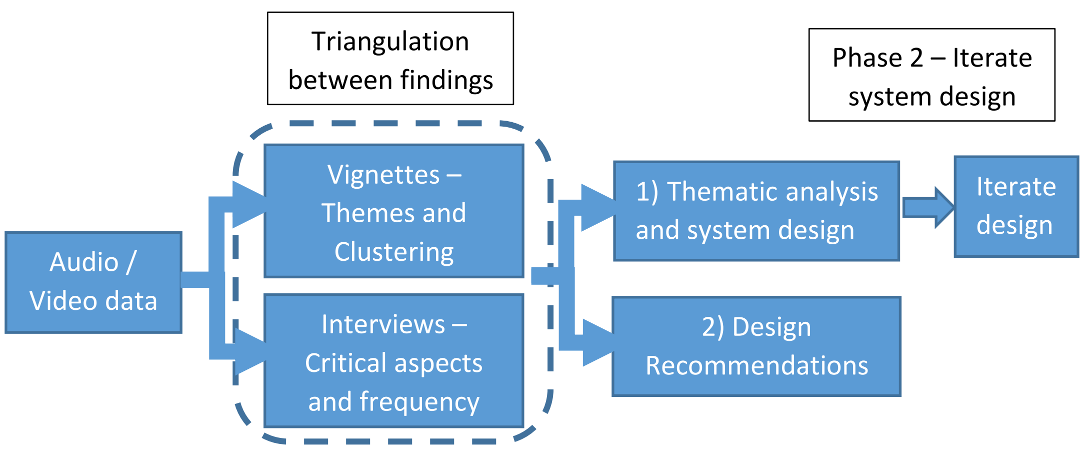


Figure 3-3: Showing the Phase 3 relationship between analysis methodologies in the triangulation of findings in generating research outcomes and themes of behaviour.

It is important to note this form of analysis methodology only takes place between phases two and three, and is intended to relate the early phenomena and thematic findings through a set of methods and models back to an HCI (Ethnomethodological) investigation. The specific relationships between each phases, data capture and analysis techniques employed in each study and iteration are detailed in the study chapters which follow. Yet the approach and analysis methodologies of each approximately follow the description given here.

3.2 Nature of Investigation

Having identified the range of current understanding in the field of multiple user display technologies and approaches within the Literature Review (Chapter 2), a consideration around the mechanism for design and evaluation of a test system will follow standardised methodologies in the field of HCI.

3.2.1 HCI investigation

Human computer Interaction (HCI), considers the design and development of computer enabled systems, addressing the comprehension and use through user centred design. This is a well-established branch of investigation featuring well defined methodologies which must be carefully considered in their application and outcome.

Considering user actions and response to digital engagement, alongside interpretations by users, digital interactive systems can evolve rapidly and form deeply engaging experiences, often exposing elements of the interaction or design not considered at the theoretical or conception phases (Paradiso et al., 1997). The role of multi-modal feedback and interpretation throughout the design and analysis phases supports a rich environment of understanding and helps to pave the way for on-going insights and development of user centred systems.

Part of the nature of interpretation is found through observation and reporting, but also in the inherent mechanisms for understanding by those colleting the data, with the situation of ethnomethodologies based on prior experience leading to richer forms of interpretation. Through grounding work in both HCI and artistic practices it is possible to assess the complex nature of interactions where there may be a limited awareness or understanding of the nature of the actions to begin with (Morrison et al., 2010). These differing approaches allow for multiple perspectives of situated works to prevent confounding findings or false conclusions.

A further case for mixed methodologies is found in verbal reporting by users around cognition and mental process. It is stated that reporting is not done via introspection, but instead done on a priori, implicit causal theory or judgment as to what extent the stimuli has an effect (Nisbett & Wilson, 1977). As such, interpretations of use must consider knowledge of learned interactions and expectations to consider potential divergences in background influences.

Within consideration of learned behaviours repeat users were employed throughout the iterations of the investigation of the system-led trials. This sought to identify how prior expectation and learned behaviours might influence response to system actions, as well more fully explore the limitations in adaptation and feedback design. This was not carried out in a "Repeat Measures Method" as there was no longitudinal data maintained for participants allowing for no dependency within their responses (Sullivan, L. M. 2008), instead responses were homogenized within the repeat user behaviours to address themes in behaviours relative to experience.

Where we consider wide ranging forms of interaction, coupled with multiple sources of data and individual interpretations, it is helpful to consider mechanisms of analysis in describing behaviours and points of interaction. In examples of free-play and open-play seen with multi-user interactive systems, it is helpful to consider cross-discipline and focusing terminology to provide a common language to experience, evaluate and report on interpretations of these experiences (Morrison et al., 2011). This can also be useful in the definition of complex actions and behaviours in a time dependant manner, such that comparisons can be drawn across multiple interactions or in defining generalised trends or approaches through behaviours.

Within this, "Reflexive Thematic Analysis" (Braun & Clarke, 2019) provides a cross-discipline qualitative method to consider codified data sets to extract emergent themes in observed behaviours and reporting of interaction and experience, where "Reflexive" consideration draws on the role of the researcher to acknowledge decisions and assumptions around the research question in drawing pattern or meaning from data. In this instance an "Inductive" approach is taken in drawing out themes within and across data sets, captured in an iterative manner to evolve the research question. Where a "Constructivist Latent" approach is taken within the analysis to relate findings back to the literature for iteration between trials, "Semantic" considerations are used in forming a "Key Words" approach to describe behaviours to provide an overarching view of an under-researched area. The codified representations were then used in a quasi-quantified analysis of behaviour distribution.

With interactions with digital artefacts it is critical to interpret the nature of the object and interaction as a part of the evaluation of the design and implementation. In considering multi-user displays, there are a range of factors which can be addressed, but may at the same time be mutually exclusive to one another. Developing any system for investigation requires the selection of a focal concept to ground the nature of the design, with; internal, external and ecological framing of displays situating the nature of the investigation to the; impact of content, understanding of users, or checking for common problems. The question must then be asked what are the final outcomes, where there are five major paradigms in developing research outcomes, with the intent being in; informing the design (ethnography, interviews), or evaluating a prototype (lab based study, field testing, full deployment) (Alt et al., 2012).

Bearing these concepts in mind, the methodologies employed around iterative development of a system may be in constant fluctuation, as the needs for alternative interpretations and outcomes will develop with the underlying knowledge around the system and its use.

3.2.2 Iterative design testing

As with many design challenges the end product is the result of iterative rounds of planning, development and testing leading to the final implementation. As an established approach in many fields, HCI offers a range of insights into how iterative development can be carried out as well as indications of outcomes of testing and validation approaches.

Within iterative development there are several pathways to constructing the final implementation formed through a number of design channels and technical approaches. Where there may be limited knowledge of the problem space or a lack of theoretical basis it can be valuable to implement multiple forms of interactivity utilising an array of couplings. This allows evaluation of positive and negative aspects and out-of-band interpretations of factors of user relationship to the object and interaction, where concurrent forms of behaviour can then be contextualised. This then leads to a final synthesis of informed design characteristics in achieving the desired interaction or experience (Robertson et al., 2006).

An alternative consideration is in approaching the problem from the perspective of design alone, where there is no theoretical or academic perspective, with the problem being placed purely in the realm of developing a solution. Where a designer will follow established methods in achieving a product, the outcome may be a very elegant and inspiring solution which then evokes a research question. The difficultly then is relating aspects of the design into an exploration of the problem space while ensuring validity and justification of the contribution, with forms of technical development having to adhere to academic principles and rigour (Zimmerman et al., 2007). If affected well, this process encourages knowledge transfer between different skills and backgrounds and may result in more diverse solutions and richer interpretations of phenomena of behaviours.

Perhaps the most established approach to iterative development in HCI practices is the formation of a research question and a step-by-step evaluation approach in identifying the gaps and boundaries, followed by a problem specification and supporting technical implementation. Where interaction metaphors are designed and refined upon via in-lab and in-situ studies, allowing for a fine grained interpretation of the nuances of the system and ultimately the identification of more diverse response behaviours in use (Izadi, et al., 2005).

While these forms of identification and development may seem at odds with one another, it is the inherent nature of the problem which may define the solution. While there are a variety of methods in addressing any form of interaction design, there are no hard and fast rules for where informed iterative design can be applied. By its very nature, iterative design assumes that not all of the information is known and so the problem must be continuously revisited, where any approach may suggest novel and insightful contributions.

3.3 Ethical assurances

Throughout all of the studies undertaken in this thesis, there has been a significant effort made to ensure that all participants are offered complete ethical assurances around their involvement in this work. Where the work has not been carried out in a public space, but in a lab-based environment the following steps have been taken;

Ethical approval has been sought from the ethics committee at the School of Computer Science, based at the University of Nottingham [Appendix A1 Research Ethics Checklist]. Identifying;

a. Risks – Protection of identity – Data Protection Act

All data is stored in accordance with the Data Protection Act, 1998, with access only given to those who are directly involved in the development of this thesis. Names and contact details are held securely and anonymised throughout the documenting and publication of this work.

b. Information used – Informed consent – Consent Form

Informed consent is ensured at all stages of studies, with information sheets provided in-keeping with the ethical approval. Participants are informed of the impact of the work and the relation that it has to the Data Protection Act. The ability to withdraw from the study and data to be forgotten is also iterated throughout. Copies of these documents can be found in the Appendix [A2 Information Sheet and Consent Form].

c. Benefits – Anonymity - Compensation

Participants are reimbursed for their time and anonymity is ensured in information, informed consent and clauses of the consent form. Compensation is guaranteed even if participants choose to drop out of the study early or remove themselves from the data sets post analysis.

d. Research method

The overall approach considers the relationship of our current knowledge of these systems to real world scenario, and investigates these factors through iterative lab-based studies.

e. Participants

Participants are selected from the local university staff and student base, along with members of the wider public where possible. There are no cultural or social restrictions, however, participants must be over the age of 18 and hold a legal status in the UK.

f. Data collection strategy

Data collection follows a range of established HCI approaches, with observation, focus groups, and structured and semi-structured group interviews. These varying data sources are considered through a triangulation approach to assess and assure validity and robustness in the conclusions and recommendations in findings and iterations of the system design.

g. Quality assurance

All participants data is held within the ethical constraints of the university of Nottingham ethics committee, which is bound by the data protection act, 1998. Participants are given an introduction to ensure informed consent in acquiescing to the study.

h. Limitations

The initial real world observations do not entirely account for all forms of interaction with digital systems and may not encapsulate the true nature of MISU interaction. The initial observations are based on an already diminished scope, due to either highly focussed lab-based or socially situated “in-the-wild” investigations. These factors should be accounted for by the experimental design and implementation of the iterative investigations.

i. Data processing

The final analysis is conducted in a manner of attention to detail and rigour, focussing on exhaustive analysis and clustering to provide the most accurate picture of MISU behaviours. This aids in situating the findings in literature and ensures accuracy and validity throughout.

3.4 Summary

This chapter has now detailed the overarching approach taken in this thesis, along with the specific methodologies employed for data capture and analysis. This is now summarised;

Purpose of research: The purpose of this research is to identify the role and nature of changing digital display layout and presentation relative to spatial organisation and emergent formations of MISU interactions. This will situate the socio-spatial and individual factors of behaviour and experience within the wider established knowledge of display use.

Main question: What is the impact of display changes to the wider use of space and how can this inform the design of digital experiences. This seeks to identify how a digital system can interpret and support natural use and behaviours of multiple users, in-keeping with their expectations of use, learning and natural phenomena, and how can changes to display layouts be applied relative to observed factors of on-going and real-time use.

Main rationale: There is a limited understanding of how low-level display interactions impact upon the wider, high-level models of behaviour and interaction in space between MISU. By considering the overall situation and forms of interaction with and around displays we can better understand how these factors inform display use and the role this has in supporting MISU experiences, presented as a set of design recommendations. Further to this, we can consider how user experience is formed relative to these interactions to consider a feedback loop between use and display layout in real time, to better support the wider use and interaction with these systems.

Chapter 4: Field Study

This chapter presents the observations and findings of the sensitising Field Work to establish an understanding of representations of literature in real world scenarios and the role of displays and content in emergent ecologies of interactions. This chapter considers interaction behaviours with and around digital displays in the wild, with an emphasis on physical space, social interactions and the role of content influencing use.

The chapter describes the selection of locations, the process of observation, the factors of spatial and display behaviours that are identified in literature, and critical behaviours related to these factors. This will outline the sensitising approach taken towards identification of user behaviours during entry, approach, and arrival in multi-user scenarios, and places emphasis on representation of user behaviours to display factors, i.e. physical situation, social interactions, content presentation and interaction type, and how these factors lead to natural phenomena of use. This aims to establish the critical factors of display use in influencing MISU behaviours for further in-depth study.

Considering the literature there appears to be a disconnect between the high-level Ecological considerations of social engagement and the low-level descriptors of phenomena of social interactions, given the inclusion of digital technologies. As such, where these systems have been deployed in the wild, there is likely to be a more complex set of inter-relationships in considering how digital displays influence MISU's. This leads to a need to establish a base understanding of what are the critical factors in display situation and delivery of content which affect entry and approach, why these factors influence use compared to previously identified factors, and how digital displays alter the expected or previously observed behaviours through their use.

Based on previous studies, which have addressed social interactions of all users - The Ecology model, as well as lab and limited socially-situated "in-the-wild" studies of display factors - there is a need to capture the ontological representation of display factors relative to emergent phenomena. These observations will inform additional studies and consider what users are being exposed to and engaging with in a variety of real world contexts.

This work was carried out as an observational sensitising approach to provide an anecdotal representation of display use in-the-wild. Given the wide range of display and content types, and situations for content delivery, this study explored how differing aspects of displays would affect their use and attempted to ground the understanding within a structure to further support a more focussed investigation around display use and content delivery. While the pictures and video data for this study were lost, this evidence did not seek to identify entirely new concepts, but instead considered generalised factors and features of displays and their use. This drew on identification of previously documented behaviours to inform the understanding around display situation and on-going use in multi-user scenarios.

4.1 Selecting Locations and Population Sample

The field work was carried out in a number of locations between the local area, Leicester and London. The early work focussed on museums and galleries in Nottingham and Leicester due to convenience for repeated observations. These locations featured a limited number of digital displays, however, the locations presented an opportunity to consider the situation of static displays and objects, and movement patterns relative to interaction behaviours.

The locations selected were;

Nottingham Contemporary: A modern contemporary exhibition space with an array of installation types, including wall mounted, walk around, and video. The space is large with a variety of content configurations and routes to engagement, resulting in a non-linear experience and alternating entry and movement patterns. This leads to interesting groupings and interactions, particularly at doorways and between free-standing installations and walls.

New Walk Museum and Art Gallery, Leicester: A "classic" museum, built in 1849 which was recently refurbished. The exhibition halls follow an established approach of single entry point and a clearly laid-out route. Several modernised spaces offer greater free ranging access, but are generally organised to prescribe the flow of visitors around and through the exhibits.

The two styles offer variety in interaction behaviour and visitor distributions resulting in an array of visitors of all ages, ethnicities and vocation passing through. With similar modern content styles the comparison of visitor behaviours can be attributed to the layout and presentation of content and design of the space. While both locations contained digital displays these were isolated television screens or interactive table tops, neither of which supported MISU interactions outside of previous examples, or account for adaptive content.

Richard III museum in Leicester: An extremely small modern space documenting the excavations of the remains of Richard III in Leicester city centre. The museum was a single large narrow room which had a prescribed route around the space. There were several large digital displays showing subtitled videos situated throughout. There was a moderate footfall given the size of the space and the majority of visitors were elderly (65+ years).

To identify spaces with PLID's and likely scenarios for MISU interactions, London was selected as there are multiple museums and galleries with an extremely high footfall and large amounts of money invested in their infrastructure. The locations selected were;

Tate Britain: Another classical museum, the design and layout is extremely formulaic with extremely large paintings mixed with portraits throughout the galleries. This constituted shared interactions around extremely large "displays", mixed with movement patterns between other points of interest. These considerations help to blend observations between the previous locations and later study of digital displays.

Tate Modern: The contemporary of the Tate Britain, this location contains diverse installation and content types. The galleries follow a familiar presentation style, however, there are similar examples as those found in the Nottingham Contemporary. This location contain multiple digital displays of varying sizes, but nothing interactive.

Natural History Museum: Having received a substantial modernisation, yet maintaining the classic style of a Victorian museum, this location provided the richest scenario for engaging content and displays of all types previously seen. As an addition, this location contain multiple large digital display showing a variety of content types and form of engagement. As a major tourist hotspot there was a significant footfall and wide range of diverse patrons.

These locations offered a variety of PLID's and content types across several scenarios. This resulted in observations of multiple relationships between the situation of the display, the role of MISU interactions with and around digital content, and the nature of presentation.

4.1.1 Process of Observation

Of the two sets of studies carried out, sensitising to physical and social behaviours was carried out first. The observations at the Nottingham Contemporary and New Walks locations offered longitudinal observations to identify areas of high throughput or interest and maximised social interactions. Observations of MISU interactions across a wide range of contexts, including; time of day, number of interacting users, etc., established a homogeneous representation of space. This resulted in a sensitising baseline to be transferred to the investigation of digital displays in similar settings.

The initial focus was to identify how and where users would enter exhibition spaces. This considered where initial entry, understanding and landing were achieved given the physical layout, line of sight, and awareness towards interactivity or points of interaction. The role of on-going use and multiple user groups was also addressed to inform the emergent phenomena. This aimed to relate the organisations of users previously described in literature to the spatial design and the ecology of use.

The London based investigations, focussing on digital displays, employed a clustered approach based on the prior observations. Multiple displays were selected and observed to consider the differences between their settings, content type and the nature of interaction to inform the impact to wider spatial behaviours previously identified. The clusters considered were; currently in use, number of distinct groups (1, 2, 3+), types of engagement (passer-by, active aware, engaged), on-going formation of users (grouped, distributed), and how these exist as parallel entities in emergent use.

Observations were made ad-hoc as it became apparent there would be a MISU interaction, clustering was then performed after the fact as several of the described clusters could form and disband in quick succession. The key findings were identified around multiple individual interactions forming from entry, to awareness of the space, to emergent phenomena of use and the influence that the display or content has in influencing these behaviours.

4.2 Initial Findings

The findings of the observations are now presented, with the observations of spatial behaviours and the emergent social organisations and phenomena described first, followed by the situation of digital technologies and their influence. These aspects are then summarised and related to one-another to describe digital displays in exhibition spaces, along with a number of design considerations for the following chapters. Given the volume of data, the following sections are presented as key findings.

4.2.1 Factors of Space and Displays

This section considers the influence of physical spaces and situation of both digital and static displays and content relative to entry and approach behaviour. This describes a number of factors in the relative entry position and how this appears to influence the unfolding interactions. This considers single users or groups entering the space and their behaviours towards the physical layout and on-going use. This is based on an aggregation of observed changes in entry behaviours across a number of on-going use cases.

In addressing only the aspects of physical situation there were three main considerations identified. These included;

- Large open space with clear lines is sight to multiple displays or interactions
- Focussed perpendicular entry to a space resulting in direct observation
- Corridors or long walls with parallel or inverted entry with limited visibility

These three cases encapsulate observed behaviours when entering spaces to engage with displays, and separately describe how physical situation likely effects emergent behaviour.

4.2.1.1 Open spaces

Seen in the larger exhibition spaces, particularly in halls and entrance ways, open spaces would allow users to assess a large number of artefacts or interaction points during entry with users and groups being free to move around the space and approach objects at their discretion.

There were tendencies for preferred direction, with the majority of users seen to move either to the left or the right and rarely enter the centre directly, even where there were examples of centrally situated content. There were exceptions, however, these appeared to be more random and individual in nature, with specific points of interest capturing attention. Typically this would include exhibits of greater visual impact, although this impact was rarely seen to propagate between exhibits, instead users would revert to the usual browsing behaviour and following the implied design layouts of the space.

This did raise questions around the role of digital technologies as there were examples of users entering spaces and being drawn to points of digital interaction, and only later reverting to more regular browsing behaviours. Unfortunately it is difficult to know the motivations of these users, but it appeared to be a major point of consideration once the artefact was identified, as was seen with later browsing users approaching these locations and being drawn to the displays as they became aware. It is possible that increasing the awareness potential of these displays would more directly alter the use of space.

Unfortunately the number of these types of interactions and data captured was not sufficient to define the nature of entry and decision making, as localised observations were made compared to the nature of longitudinal behaviours. Further, the number of individuals in these larger spaces was low given the high footfall throughout the exhibition space. As such, observations were simplified to consider localised spaces. These are now discussed below.

4.2.1.2 Perpendicular entry

Considering a more focussed entry condition with smaller entrances and reduced space, where the user was quickly presented with the exhibits but also able to identify the nature of the layout. This considered cases where content was presented opposite to the entry position at a distance of several meters allowing for a clear line of sight and sufficient space to become aware of the layout of the space (Figure 4-1). Narrow or occluded entry to these spaces limited awareness of content until entering the space and being presented with the layout from a removed position. Exit points could be situated anywhere along the perimeter of the space, or via the entrance point, but were clearly identifiable as a component of route planning. Being able to assess points of interaction and the exit position lead to fairly repetitive behaviours. Users in isolation were seen to simply follow the flow of content from one side until reaching the exit.

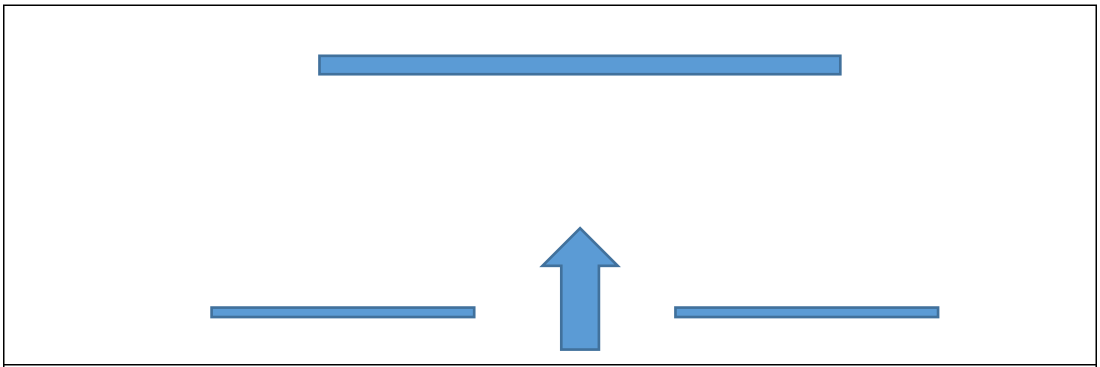


Figure 4-1: Showing the perpendicular entry position relative to content presentation.

Digital technologies influenced this behaviour, with approximately half of users being drawn to these locations during entry, as a combination of either; situation of the display making it immediately accessible, or natural draw of inquisitiveness. The second of these points appears to be the case given that users would often approach displays while completely ignoring other aspects of the content before moving through the space as may be expected, but in many cases ignoring the initial section of content as would be seen in normal flow behaviours. This suggests the display alters the flow through the space as users engage and then continue with exploration.

Here, the context of display use and presentation is seen to play a further role in spatial behaviour, with varying forms of presentation and content types, along with display size and on-going use influencing approach behaviour. Increased awareness of multiple points of interaction mitigates approach and testing of social boundaries, with greater opportunities for distribution around the space and avoidance of contextually busy interactions relative to the spatial design, appearing as spatial turn-taking, and not direct approach to displays.

Where the entrance is focussed within the space there is a greater ability for users to assess flow relative to the content and to more effectively manage social boundary interactions through route planning and turn-taking. With multiple points of interaction available during entry users are able to avoid boundary interactions or conflicts by managing their behaviour to greater support social organisation. In cases of high throughput or subjective draw to points of interaction or Honey Pots, the social boundaries are formed through intentional actions and so conform more closely with expectations in behaviour, such as line formations and turn-taking, although this is at the discretion of individuals and groups, however, this is generally mitigated by a greater initial awareness of the affordances of the space and content presentation.

Importantly, the locations of points of interest relative to the wider content are quickly determined and inform entry. With approximately half of users following each action this suggests these points of content are highly attractive in a given setting, with individual preference for subjective positive, negative, display, and social experience driving decisions. With the inclusion of digital interactions it is not clear how presentation of content and on-going use might then influence or inform entry and approach behaviour, or how adaptation of a single large display can alter the context of use to support or mitigate boundary interactions in facilitating MISU interactions in this scenario.

4.2.1.3 Parallel entry

Parallel or inverted entry considered cases where the content was not immediately visible to the users, either being along the length of a wall or corridor, or in more extreme cases, where the display was behind a wall along the main movement path (Figure 4-2). Both examples limited the line of sight to the length of the display and would require users to orientate to the content before moving along the length in identifying points of interaction. This produced a combination of factors between the two previous cases (open spaces and perpendicular entry), with the path being clearly defined, but no part of the content being immediately accessible until in close proximity.

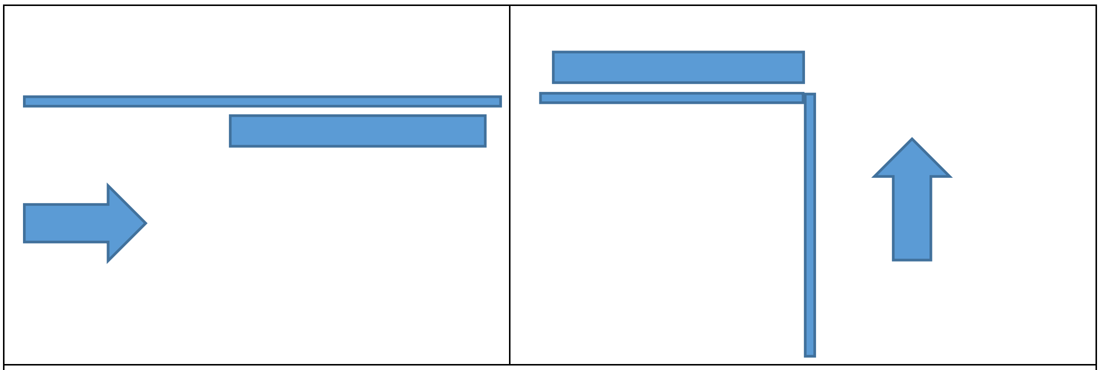


Figure 4-2: Showing the parallel (left) and inverted (right) entry position relative to content presentation.

This layout would result in a generalised movement pattern through the space, engaging with objects as they became visible. This was seen to be relatively exciting to users as they passed through the space and discover points of interest and interaction, but distinctly limited the potential for approach and engagement due to poor awareness of later articles. Users were only able to engage from the end of the display or content, being forced in to social interactions with on-going users or to by-pass on-going groups based on the current configuration. Unlike the perpendicular case where there was greater opportunity to spread out and inform the approach position, the interaction of social boundaries is less informed and more prescribed during approach.

Here the requirement for social boundary regulation and negotiation between groups is far more abrupt as users are required to form social organisations whilst simultaneously becoming aware of content and their subjective draw to points of interaction. When approaching on-going interactions the “hidden” nature of content either at the point of interaction or beyond reduces approach to either a boundary re-organisation, boundary conflict, or retreat towards the general flow of the space to support avoidance or greater awareness, leading to a juncture or breakdown in the interaction. In contrast to perpendicular entry, informed social organisation for turn-taking or line formations around a point of interaction is harder to achieve as the point of entry to the interaction is restricted by the approach being in-line with the flow direction, reducing the overall awareness of spatial affordances.

When considering digital content, there was again an approximately equal split in identifying digital interactions. This appears to be down to significant aspects of the physical situation and relative layout of other content causing avoidance or distractions leading to missing the display entirely. There also appears to be aspects of the content type and nature of the interaction in identifying displays. These were seen to be two-fold, with static content, or a lack of interactivity, appearing to be boring or less relevant to the space, but also with dynamic (video) content being in the middle of a loop or at a point of re-setting so being ignored or perceived as too much effort to back-track. This was also seen to be context dependant, with the type of content and forms of on-going interaction altering approach behaviour.

Where digital content is present there are clear issues around boundary interaction and conflict and breakdown during this form of approach. Issues of reduced awareness limit the potential for shared interactions, or impose social pressures during on-going use which must be handled through social negotiation. It is not clear how factors of single large displays may better support these types of actions in approach behaviour, or how content presentation and layout can be utilised to mitigate boundary conflict and maximise utility.

Ultimately, each condition presents different impacts upon the decision making and use of space for users in isolations, but this is not only related to the situation of the display. The nature of the content type and interaction were seen to form the context of use and influence both awareness and interest. These observations lead to a two part consideration of displays in the wild. Firstly, the presentation and nature of content interaction informing the context of use given the situation, and secondly, the implications of changing social organisations and the impact to barriers due to factors of approach and on-going engagement.

Both the parallel and perpendicular cases show a range of different challenges to social boundaries during approach, where users in open space can simply avoid social interactions and boundary creation or conflict. The inclusion of varying forms of interactivity and presentation can alter not only the perceived physical configuration of a space but the social interpretations of boundaries, and influence the formation and impact of social phenomena as centres of organisation. Understanding how these factors come about and the impact this has in the wider space can then inform potential strategies in support and management of these emergent factors.

4.2.2 Observed social phenomena

By assessing similar forms of interaction and the inclusion of digital displays and forms of content, the changes in emergent phenomena could indicate where and why these factors may be influenced by changing the context of an interaction through adaptation of display layout. This section considers emergent social phenomena and points of interest in how layouts, types of content presentation, and on-going use influence user behaviours and where there is a need to consider these changes as a mechanism to support use.

This will consider two examples of multiple user group interactions with similar situations but presenting differing content types. This will compare the influence of digital content, the manner of social organisation and the barriers and influence of social phenomena to approach. This will be followed by a third consideration of dynamic (video) content usage.

Each example will consider the following factors;

- Route-planning
- Awareness
- Honey Pots
- Shoulder Surfing
- Line Formation
- Ownership
- Learning
- Turn-taking
- Proxemics
- F-formations

The first example shows users entering form the right hand side from the parallel entry condition and moving along a large display case of approximately 5m. The case shows a number of physical objects which are laid out as a scaffolded series of interaction points but no digital content. There is a single podium mounted tablet to the left of the display. The example (Figure 4-3) shows three top down "snap-shots" of an emergent interaction between multiple groups. The position and approximate social boundaries considered by the Proxemic and F-formation frameworks are shown for each group along with route-planning.

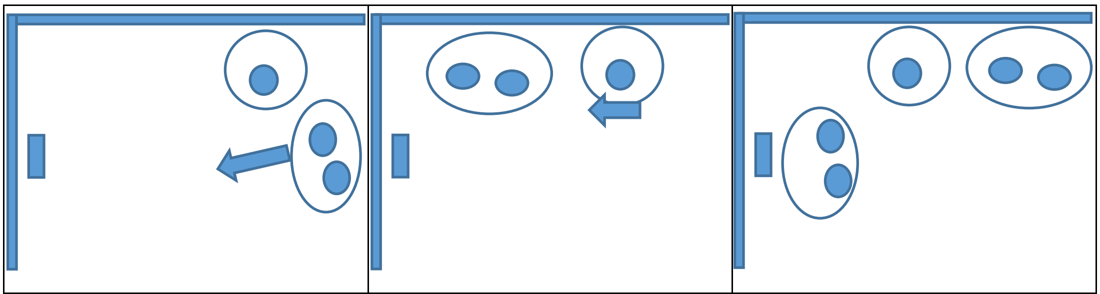


Figure 4-3: Showing a number of groups entering form the right hand end and observing content as they move along a large display.

A single user is seen at the right end of the display showing multiple static items. As two new users enter they move away and behind from the entry point and aim towards the left end of the display, approximately 2/3 distance from entry, avoiding boundary interaction. There is an awareness of the on-going interaction and the likely future movement behaviour. The individual users begins to move to the left as a second group enters, with the group slowing as the space to the right becomes available. This slowing action allows spatial turn-taking with no need to cross the F-formation or Proxemics boundary. The initial avoidance and route-planning of the second and third groups are influenced by the single user and their position and behaviour.

The on-going awareness of the social boundary and movement between the first group and single user appears to influence the decision and the group do not form a strong interaction with the content to the left. Their attention shifts and the tablet display is identified and their formation re-orientates to the tablet during their approach. Their closed F-formation with the tablet does not present further awareness of the digital content or an opportunity for joining. Given the size of the tablet and nature of their interaction there is no Honey Pot formed.

With the limited draw of static observable content and multiple scaffolded points of interaction the dominant factors of use were seen to be social boundaries and movement pattern. Aspects of slowing and turn-taking allowed the interactions to the right without any perceived pressure upon social boundaries and a learned understanding of the movement pattern in the space flowing from the entrance. By "leap-frogging" the initial social boundaries of the single user towards the left allowed for a group interaction at an alternative point within the display case, however, an awareness of future movement and perceived ownership of the single user to the wider case in-keeping with the flow and their on-going engagement limited the interaction. Instead of impacting the social boundary or on-going interaction, the first group explored the immediate space and were drawn to the digital interaction where their emergent formation showed a closed interaction and ownership.

In this parallel entry condition there were clear implications in the flow and ownership of the series of scaffolded interactions available. In avoiding creating social pressure through boundary interaction, avoidance and retreat behaviour allowed for greater awareness but at the cost of breaking the sequential interaction design. The later entry was able to utilise delay and turn-taking to maintain connection to the interaction without incurring a social penalty, however, this was tightly coupled with the spatial organisation at their point of entry i.e. there was more space available to the right of the display.

As users in later entry were able to identify a social context of the interaction it was possible to manage movement and route planning, however, it is not clear how these behaviours would be influenced by altering the context through the inclusion of digital content or a single large display.

The second example (Figure 4-4) considers interactions between multiple groups around a single digital display of approximately 1m wide and 2m tall, showing changing information about the exhibition space, leading to interest and high dwell times. The display is in the parallel condition in a very wide hallway or transition space between two large open areas, with the space being around 8m wide by 5m deep. The position and approximate social boundaries considered by the Proxemic and F-formation frameworks are shown for each group, with route-planning and awareness indicated and discussed below.

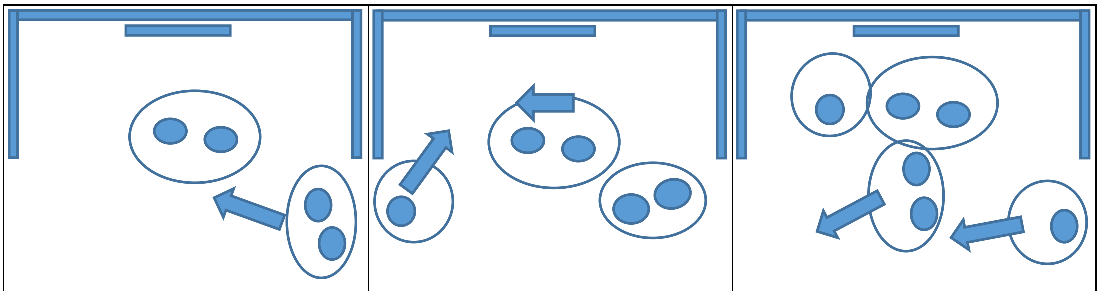


Figure 4-4: Showing a number of groups passing through and large space and forming a number of interactions behaviours around a single display while in use.

The initial on-going group shows an open F-formation at a removed distance, allowing entry positions to either side. The second group entering identify an awareness to the digital content and alter their route-planning. After approach their position is to the right and behind the group, adopting a shoulder-surfing position along with a non-committal orientation to the display and formation, allowing awareness and learning about the content.

This position results in conflict at the social boundary and the on-going group moves to the left, freeing line-of-sight and maintaining their formation and ownership towards the display.

An individual user enters from the left and identifies the Honey Pot and digital display. As they approach they identify the movement and interaction between the two groups, with an awareness to the social interaction, learning about the nature of the formation. The user slows and alters their approach to the left, allowing spatial turn-taking in movement. The single user joins in a line-formation, giving stability and a shared interaction to the formation.

The second group is not interested in the content and change their orientation to leave the space. A second individual user enters from the right. They have an awareness of the Honey Pot but not the display. The movement of the second group leaving causes the user to slow and alter their route-planning away from the group. The slowing indicates spatial turn-taking in preventing interaction between the social boundaries. The single user identifies the display but continues to move through the space, they have already made a correcting action to support the exit of the second group and maintain this response with some glance behaviour to the display.

In this condition approach was towards a single point and so inherently shared by those in the space. While there was a large space available to assess the on-going interaction and flow, approach was restricted to the most direct approach position. In order for multiple interactions to take place there was a requirement for social boundary interaction and negotiation to take place, with the second group instigating the re-organisation due to their approach relative to the initial formation in use, resulting in social organisation through shoulder-surfing and line formation.

As the scaffolding of the display presented high density and changing content within a single limited display size there was a heightened requirement for focussed interactions as the number of parallel users increased. Where an initial loose formation was able to observe all changes easily, the inclusion of new groups required a more considered organisation to support line-of-sight and learning between groups without impacting the ability to engage with the changing content. With each additional entry to the formation a stronger sense of organisation was achieved in managing social boundaries leading to a learning of social context.

With the display being readily visible but structure of the content presentation being prescribed, the numbers of users and their ultimate social organisation was quickly achieved with minimal interruption or boundary conflict. Yet it is not clear how any changes to the presentation or area of the display may have affected the manner of organisation, or how additional approach behaviours may have taken place.

Between these two conditions the first example saw no significant impact from high awareness points of interaction between users i.e. digital content, and was entirely driven by social organisations. The multiple points of interaction allowed for complex route-planning, but did not support mitigation of social boundaries. Instead turn-taking and avoidance were seen in preventing impact to interactions, with formations and movement patterns used to demark areas of use. Perceived ownership of future space was seen through an awareness of an on-going interaction, which reduced the potential use “downstream” at the display. Where local points of interaction could be found i.e. the tablet, this was seen to be outside of the context of the on-going interaction and so offered an alternative.

In the second example the single point of interaction had a significant impact upon awareness and approach, however, the initial position of the formation relative to the dimensions of the display allowed entry positions, but not for a readily shared interaction. The draw of the Honey Pot created social pressures within the interaction which were both subjective, due to approach position, shoulder surfing, and preference for personal space, and due to the physical presentation of the content. The single point of interaction with multiple entry points did not convey sufficient information for approaching users to form an awareness or understanding of what they were engaging with. Instead, shoulder surfing to allow learning was required and resulted in local adjustment causing the organisation to move towards a more rigid structure in engagement.

The interaction of users about the display appeared to influence further approach behaviour, with local adjustments being identified (not as a factor of display change but a result of on-going use) causing the single user to slow and “wait their turn” to approach, before joining as a line-formation and creating a stable interaction. The approaching user had little knowledge of the content or their interest in it, and so the stable line-formation appears to be related to a social learning due to the impact of shoulder surfing, and not only a physical requirement to engage, but a social requirement not to interrupt the interaction again.

The final impact of the display behaviour is the final user entering, where the Honey Pot is identified but the large number of people exhibit a formation that does not present an entry point or clear line of sight to the display. The leaving behaviour of the second group appears to further reduce the attractiveness and introduces a movement pattern in to the space. This is handled through slowing and social turn-taking, where route-planning allows for a small pause to prevent social boundary interaction.

This social relationship of turn-taking seen in movement in both examples does not directly consider the display as a factors, but can be seen to be influenced by actions and behaviours about the display. This leads to considerations of how a display might influence those directly at it, but also ways in which a display might influence entry and approach behaviour in either mitigating these wider impacts, or in supporting users in approach.

The final consideration of display interaction is around video content. Shown below (Figure 4-5) two large television displays were situated along a single wall, with around 2-3m viewing depth to the opposite wall, with viewing area shown in green. There were multiple items of static visual and written content shown along both walls, with one wall tapering away to allow greater movement flow around the second display.

This was seen to have a significant impact in social and spatial organisation given the nature of the content. While static content presents fixed factors to the space, giving rise to social phenomena, video presents a fixed time frame, or shared turn, within its situation. As such, boundaries of interaction are related to the physical presentation and the local density of use, with social boundaries having an inverse relationship to the number of people sharing the viewing area.

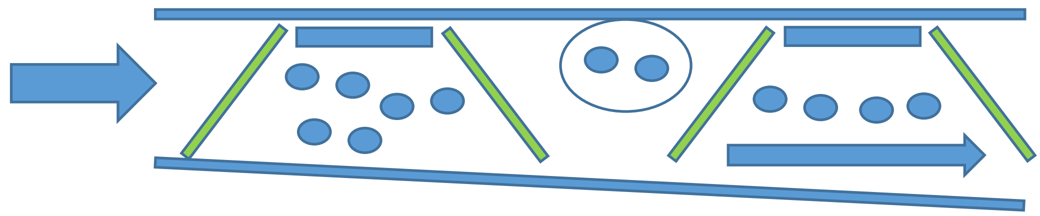


Figure 4-5: Showing the situation of two displays showing video content

These organisations of users still maintain entry points, but issues of shoulder surfing and proximity are significantly reduced as local user groups form distinct F-formation about the display. These local formations will then define movement paths through the space as line-formations or inferred zones-of-use become tightly coupled to the display and content. Where users were seen to enter the interaction late there was significant drop of in engagement and user would instead engage with static content. This was seen to be both a part of the flow of the space, but also as a turn-taking strategy in waiting for the video content to loop where the start had been missed.

As the interaction is of a fixed length and is shared between large numbers of users, the awareness of impact of entry/exit and re-organisation to on-going interactions appears diminished, although there are still considerations for local interactions and speed of actions within re-organisation. As the space available at the first screen was more tightly constrained, the actions of entry and re-organisation seemed to be more readily tolerated as this was also the entry to the wider exhibit space. However, once having passed this point the organisation at the second display was far looser, with individuals and groups showing greater awareness towards the static content available during approach, and breaking away or moving around and behind formations of users at the second display to then come back as the content looped.

With the inclusion of video the scaffolding between multiple points of content interaction were blurred between the boundaries of video interactions and static items due to the nature of the fixed time frame for interaction with the video. This saw the initial organisation being far more tightly coupled to the content and its presentation than to social behaviours, with transitions across boundaries to static content reverting to social organisation when leaving the interaction with the video.

As awareness and exploration were essentially prevented by the formations of users relative to the fixed time frame of the content users quickly adapted to the limitations of the space over social boundary negotiation, with breakdown in interactions appearing at high densities or missing the start of the video. This initial awareness towards the need for social organisation then appeared to inform later behaviours towards static content and the second display, with clear avoidance behaviour towards clusters forming at the display in favour of delaying behaviours or wider exploration.

This now raises the final point of multiple user groups about displays, where an external constraint on time and a need for stability in organisation is seen to mitigate the impact of social boundary interaction. Here the role of the display as an attractor can work adversely where there is a time dependant interaction required. As social boundaries are mitigated through the nature of the content, the role of presentation and adaptation are better suited to factors of the wider environment in preventing further unnecessary impact to on-going use and raises considerations for how a display can better support out-of-band use where there are contextual considerations in how the display is influencing entry and approach to localised interactions.

This now leads to the main considerations;

- Formations of users at displays affect the overall use of the space. These can lead to avoidance behaviours, or indicate an interaction or shared experience and points of entry. Formations also give context to interactions and shared experiences to define the forms of social interaction and boundaries leading to stable use. While social phenomena outside of the expected context may emerge, there is an opportunity to consider mechanisms and support in mitigating these forms of boundary interaction.
- Varying forms of presentation will alter the context of use and influence emergent formations. Understanding how presentation leads to use cases and the relationships of user interaction behaviours in these scenarios can support real time display changes to encourage or mitigate various boundary interactions.
- Interactions between formations of users can convey additional contextual information to the space. These forms of behaviours imply a need for certain entry and approach behaviours in achieving a stable interaction.
- Multiple points of interaction offer opportunity for exploration but introduce considerations of ownership and movement patterns in defining context of use. The nature of the overall experience and local type of content presentation defines the nature of boundaries and influences the interaction behaviours.
- Shared stable interactions allow for social boundaries to be softened but these must be within the context of the interaction, seen in the type of content presentation and the formations. Specific types of boundaries around approach and engagement behaviours remain, but could be mitigated through understanding on-going use.
- Perceived ownership of an interaction can mitigate social impacts and help to strengthen interaction between social boundaries. Ownership can be inferred through formation and on-going use, but also implied through context of an interaction. Users can actively influence their ownership to an interaction through their behaviours within the bounds of the design and presentation of content type.
- Formations of users will define ownership and entry and approach points within the context of the presentation and on-going interaction. Understanding the relationship of awareness to on-going formations and interactions will inform how, where, and why changes in presentation influence the use of space, applications for layout adaptations, and mechanisms to support and mitigate boundary interactions.

4.2.3 Interaction type and the nature of user experience

Throughout the observations it was seen that the context of interactions would strongly influence the emergence of phenomena. With variations in the content type and interactions for given display situation, each form of content presentation would alter critical components of user interpretation and approach. This presents an area of consideration, with varying forms of content altering the influence or likelihood of phenomena of interaction when compared with the static, or expected interaction behaviour.

Considering what was seen and examples from literature the behaviours of content can be characterised by a spectrum of presentation types, describing approaches to displaying content on displays in the same situation, yet eliciting differing reactions. These are;

Static: The content is static and does not change in any manner based on viewing, engagement or interaction. This is the established display paradigm seen in museums and galleries. This is the lowest level of presentation and is described by factors of physical and social situation, such as optimal viewing position, Honey Pot effects, clustering and turn-taking. While there are cultural and artistic factors which may influence the impetus to engage with the specific item i.e. The Mona Lisa, the defining aspects of physical situation, configuration and physical space about the object will define the nature of engagement. With the approach given by situation, and number of points of interaction being managed through established social organisation, the outcome of use is well understood.

Dynamic: Dynamic content has some form of layout or presentation change associated with the overall presentation of the experience. This can include video with audio or subtitles, or advertising or information displays. The nature of these interactions is time dependant, as there is a distinct beginning, middle and end to the experience, and as such, a limited timeframe to fully engage. This introduces considerations of line-of-sight and shared spaces or experiences, where there is an imperative to engage with the full experience, this could be construed as a social pressure to share spaces or manage social interactions to support this requirement and maintain an on-going interaction. Dynamic content also introduces considerations of attractors and awareness in to engagement outside of underlying spatial clustering and “Honey Pots”, as we are attuned to visual movement in our local environment, potentially leading to an interaction. As the content is time dependent the emphasis shifts to a shared social interaction and organisation to allow equal access. Here the expected social conventions are softened at the need for organisation.

Responsive: A user focused change in the presentation of content that is aimed at locally supporting single or small groups of users. This is not interactive in the sense of the user directly manipulating the content, but instead is a more passive relationship to better support use in line with the design. This could consider small responses to local user actions, such as approach driving an aspect of an interaction i.e. lighting or sound. The emphasis is in local awareness, where the change is visible but does not necessarily alter the wider use of space or the manner in which other users may become aware or approach the interaction. These actions may work to both encourage or raise awareness of the responsive state, or localise the interaction to a formation, setting the context of use to a single user or group.

Adaptive: Adaptive content is described by content presentation or layout changes managed by the system in relation to some aspect of the environment or engagement of users, but is not a form of interactivity, such that there is a direct manipulation that benefits or supports the user in that action. An adaptive interaction may consider how groups become crowds and the presentation of the content must adapt to support more users engaging, potentially by limiting content and changing the size to be more readable. Alternatively, this could also consider content changes based on environmental factors, etc. to better facilitate natural engagement. Examples of this include automatic display brightness or audio levels relative to ambient noise. Where the boundaries of adaptation can be identified by users and manipulated, this could be considered as a low-level interactive experience, however, with adaptive content there is no direct benefit to the user outside the initial exploration of the artefact. These changes can work to alleviate perceived design issues or edge cases where it has been considered that the normal expected social organisation may be impacted. This presents an ambient factor and adds no additional pressure to social organisation.

Interactive: Interactive content exhibits some form of user manipulation in the presentation and or layout, and so introduces a dynamic, but also social influence to the experience and use of space. Where static and dynamic content have specific influencing aspects to social and physical engagement, interactivity now introduces a personal-social relationship, with learning effects and social pressures etc., adding a specific relationship between and within users (Performer/Spectator). As a partial social entity, the display introduces both feedthrough and feedback to users as well as spectators across a range of factors, from zones of use to learning, and so inherently influences the wider use of space and the role of behaviour seen. Where this is limited is in the breadth of interactivity for those in the space, with the majority of these systems being fixed to single points of interaction. Although there are examples of multiple users acting in isolation on a single display, this draws another problem of how to rectify multiple simultaneous changes to the display between users and how this might be interpreted by observers, defining a tightly coupled context of use.

Predictive: A predictive system could be considered as any system which adjust its layout or presentation with some informed rule set, with a relation to future behaviours or engagement of users or user groups. This expands upon the concept of adaptation by introducing a future “understanding” based upon a user “model”. This model could be likened to the interaction-response relationship of interactive systems, where instead of relying on user learning and understanding to drive the layout change, the system interpolates through the current behaviours and states of users relative to this model to present a “likely” or predicted outcome. This fundamentally changes the nature of the engagement for the user, but may also introduce issues of lack of understanding of the changes relative to the behaviour. Further, it is not easy to predict the interactions of multiple users or how this should be conveyed to the wider space. An example of this could be using gaze estimation to highlight information, such as with advertising, or to another degree presenting a user with further information, such as menu options in “pre-empting” a slow or novice user who may be struggling with an interaction, although this would not be purely based in the users current actions but instead in their lack of one.

This “spectrum” of content presentation types considers an evolving relationship between the fundamental aspects of interaction based upon physical and social space and the impact of content and interaction behaviours which influence emergent phenomena. By incorporating the nature of individual and group experience around these aspects of system interaction we can consider how altering factors or varying types of content presentation might influence the context, and so influence the use and impact of the display.

Through the escalating relationship of forms of interaction, display presentation becomes more socially orientated and acts to directly influence local organisation and global behaviours, with the implications of layout changes becoming harder to identify through low-level social phenomena. By addressing user experience around factors of layout changes and interaction we can begin to identify and inform these specific aspects of displays.

While there are many well documented examples of these types of systems (with Predictive being the exception), with considerations of their nature and role in influencing spatial behaviour and phenomena between users, the significant short-coming is found in how these knowledge bases relate between one another and how changes in established interactions can inform to support or manage the emergence of social phenomena.

4.3 Critical Characteristics and Behaviours of Displays

Having presented observations of the Field Work we can consider critical aspects of both the users, and more importantly the display, which influence the observed interactions. Simplifications in the physical situation describe the general nature of display space. Following this, the considerations of social use introduce the wider implications of how multiple simultaneous users are aware of and informed by display changes, and further, how this goes on to influence the ecology of use.

As a part of this discussion the spectrum of content types will not be directly considered as there were a limited number of examples, with the remaining information being drawn from literature. Instead, limited considerations of how changing layouts were seen to influence the use of space and the impact to the remainder of the investigation will be presented.

4.3.1 Physical situation

Relative display situation has a marked effect on how awareness and unfolding interactions take place between MISU's. This is described by either an approximate oblique (perpendicular) or acute (parallel) approach angle, and describes several critical issues with displays in social space.

The first of these simplifications see's users approaching the display head on from a perpendicular entry, and appears to supports natural awareness and learning for users as part of both a wider awareness of the layout and nature of the space. This factor supports how MISU's interpret the interaction context separately from one another and engage in a manner that is initially more naturally suited to larger numbers of users. The limitations of this simplification appears in how users are drawn through the space as part of a natural flow or understanding of the layout, as early awareness can draw users away from other points of interaction or aspects of the space which may inform towards the design or flow, such as sequential exhibits.

The second simplification of parallel entry considers a lengthwise approach towards a display leading to a movement focussed result, where the design of the space encourages flow through and around, but does little to support discoverability or engagement for a number of reasons. These include; the nature of content and how it is displayed, the number and organisation of on-going users, and the relationships between multiple pieces of content or points of interaction. Within this, social configurations and layout of content were seen to greatly impact upon the ability to identify and interact with displays, where on-going interactions present boundaries to greater awareness of the space and require a response during approach. As the nature of the display and interaction only become apparent during approach the role of the display is significant in how it elicits and manages on-going interactions, but also informs and supports additional approach behaviour.

When considering the structuring or scaffolding of content on displays both conditions are seen to affect how approach behaviour unfolds relative to what can be seen and on-going use, but there are clear limitations in how both conditions can influence the potential for MISU interactions based on boundary formations relative to these layouts. As digital displays are able to alter their layout and presentation a further investigation of how natural organisations form relative to content and the interactions of social and interaction boundaries will help to more fully understand these factors.

4.3.2 Social interactions

Perhaps the most important aspect of engagement with content is the nature of social interactions. Of the observations made of previously identified phenomena there are several critical elements which may relate components of wider spatial behaviour to describe the use of physical space, as well as elements of social organisation at displays. More importantly, it was possible to begin relating these two sets of factors to components of display layout as centres of orientation and influence to local and wider spatial decision making during entry and approach.

When characterising social behaviours, the approach considered emergent social phenomena in relation to the on-going context of use. This addressed both the type of content and forms of interaction taking place to assess how and where social interactions and boundaries were formed. Considering how the context of an interaction formed given a similar situation, this looked to identify where boundaries and behaviours might be altered between these conditions to inform the impact of display behaviour and the role of scaffolding layouts and interactions in influencing use.

Perhaps the most critical elements of social behaviours were the configuration of users at the displays and learning effects associated with these localised groups. Where there were elements of Honey Pots drawing users in, this may support learning via managed social boundaries, however, the tighter clustering seen in turn taking was a more definitive example of learning between users while also impacting upon and creating boundaries. As a natural component of use this supports wider factors, but at the same time introduces elements of user interaction and ultimately experience as a component which may not be ideal or have a negative impact. Understanding how these formations arise relative to scaffolded or structured layouts and the impact this has in boundary formation, negotiation, and management can then inform towards display adaptation as a driving factor within interaction experience.

As a part of this, each of the factors identified; Ownership, Configuration, Honey Pot, Roles, Turn taking, Learning, Awareness, Changing layouts, Zones of use, etc., were seen to influence how the use of wider space changed and related to individuals as the decision makers in enacting that change. As such, it is important to consider how each of these elements is presented and interpreted by the individual users during entry and approach relative to structured layouts as a part of emergent behaviours, and how each of these factors influences the wider space as a whole to best describe their use in adaptation. These factors now become a two-part consideration of display presentation, as either; a direct mechanism for changing layout and the impact this has, or as a consideration of how factors are being interpreted by users and why.

This brings users experience to the fore-front as a mechanism to assess both the local and global changes of layout and the impact this has to user interpretation or expectation, as well as a mechanism to report how changes in context can support and manage underlying social behaviours. Given the depth and complexity of the problem space involving MISU's, this should provide a simple set of relationships between use and potential changes to the layout across a number of use cases, such as those described in the changing nature of content and interaction type, given that this is not currently well understood.

4.3.3 Layout changes

As the centre of focus in these scenarios, the nature of the display layout and behaviour is pivotal in the interpretation of the observations. Considerations of situation and content type were seen to critically influence not only individual awareness and engagement, but the manner of wider awareness and social interaction throughout the space. With the situation of the display and social organisation it is important to focus on the display as the route-cause of observed and emergent behaviour in relating behaviours and organisations to the structure of the content.

Where multiple points of interaction will present localised scaffolding for interaction, considerations of the context of use and nature of content will influence boundaries of entry and approach, with boundaries between types of content altering the governing factors for localised spatial behaviours. With formations of use tightly coupled to the local scaffolding, the use and interaction with that content becomes a driving factors in the negotiation of boundary formation and management as a centre of orientation for wider awareness. In understanding how structured layouts and types of content and interaction influence factors of use, an overall relation of user experience can compare varying forms of content presentation to given situations in describing wider MISU behaviours as both a supporting and mitigating factor.

Limitations appear where social organisations to local scaffolding give rise to breakdowns in interaction through entry and approach, such as altering flow or impacting on-going experiences. While subjective boundary regulation can be formed relative to multiple points of interaction and their social organisations, localised context of use is directly linked to the structure of content and its presentation, which is not related to the ecology of the wider space, meaning that multiple points of interaction can exist in parallel but will begin to influence one another as soon as there is an engagement formed.

As such, the role of the display and content presentation should be at the heart of any investigation aiming to address the nature of social behaviour with and around displays. Where multiple users are engaging through a number of zones, models, social behaviours, etc. and do not interact with the display directly when influencing or informing one another, this suggests any investigation must consider displays which support MISU interacting with discrete points, and the manner of layout changes to multiple points of interaction influencing formations of use. This ensures that any uniformity in findings can be related across all forms of content interaction and out in to the wider space to convey a behavioural impact.

4.4 Conclusions

While these observations have identified previously established physical and social factors of display situation and use, the limitations in size and nature of content interaction presents a significant issue in assessment of an ecology of display use. While further investigation of the current range of digital displays would likely prove informative, the lack of interactive and adaptive displays for more than a single user limits the manner we are able to consider MISU's around points of interaction. This presents an initial stumbling block in effectively identify the role and nature of display use.

Where spatial and social aspects of display awareness and attractors indicate elements of content presentation and type play a significant role in the formation of boundaries of use, this suggests an area of investigation as to how these factors relate and impact on-going use as well as experience. Given that there are bodies of work which identify how layouts may inform groups, it is still not clear how this relates MISU's to configurations of use and real time experience. While the use of static and dynamic layouts present a simpler problem space to assess this relationship, this does not offer scope to assess dynamic, adaptive or interactive content, and does not present a true image of MISU interactions around displays.

With consideration of previous findings around display behaviours, many of which were identified in isolation, and the relationship these share to the complex nature of in the wild studies, there are several comparable factors that have be identified. The limitations in these approaches, however, is the wildly complex nature of MISU in public settings. Given that each user observed held no single agenda or similar rule set, any attempt to apply a single social or physical rule to real time behaviours is vastly complex, and so a number of simplifications are required in identifying general behaviours.

The use of simplifications to compare and contrast these behaviours leads to an area of potential classification and further analysis between these fields, where a process of cross-comparison between social and display contexts may lead to a more accurate classification of real time behaviours. While this approach would give scope to considerations of changing presentation and content types, the major limitation is that these fields have not currently been related and so would require a significant body of work to situate the approach before attempting to assess MISU interactions at a single display.

Initial simplifications were however identified in the entry condition to display spaces, such that parallel and perpendicular entry were seen to influence emergent behaviours and present distinct issues around boundary formation and interaction. When taken in the context of entry and approach there were also indications that the structure and localised scaffolding of content played a significant role in social organisation, with the context of use defined through the type and presentation of content and so informing wider socio-spatial behaviours, with the limiting factor in these observations being the static nature of content presentation.

This said, these considerations suggest that the most valuable course of action would be to focus on a system based investigation to identify the nature and role of content presentation and type within on-going interaction behaviours to better understand how natural organisations of user form about structured and scaffolded content before considering the interactions between multiple points of interaction. In this way, the body of knowledge around displays and their cause and effect relationships to crowd dynamics and behaviours could be more accurately assessed before being applied to the real world scenario.

4.5 Summary

This chapter has now presented the findings from the sensitising ethnographic investigation, showing the apparent limitations and relationships between previous findings and complex real world scenarios. The work goes on to expand upon and describe the nature of content and interaction types and the influence this may have to interaction and engagement between simultaneous users. Finally, a discussion of the relationships between the factors of physical, social and display behaviours is presented to help in the understanding of the problem space as initially described in the Introduction chapter (Chapter 1: Introduction).

This chapter has now answered sub-questions a) and b) from objective 1, in presenting the relationship of prior findings in the context of museum studies and goes on to outline the critical aspects that displays play in these interactions. The work goes on to describe potential factors which may relate displays to behaviour which will be further addressed in the introduction to the following chapter (Chapter 5: Study 1 – Wizard-of-Oz).

In total this chapter presents a two part meaning to the thesis, with the sensitising component helping to focus the understanding and awareness of interactions and the use of digital systems, and the second presenting a number of design and user factors to inform further investigation. These design factors will be considered through a more focussed lab-based investigation presented in the following chapter (Chapter 5: Study 1 – Wizard-of-Oz).

Chapter 5: Study 1 - Wizard-of-Oz

This chapter presents the findings of the lab-based "Wizard-of-Oz" trials to assess the impact of layout and presentation changes of a large digital display during entry and interaction. The investigation draws upon the findings of the Field Work and literature to construct a series of sensitising user trials with the aim of identifying themes in group interaction and display presentation. This study considers a wider range of layout, presentation and dynamic factors and relates these to observed user behaviour to present a thematic interpretation.

As a part of the justification for a full scale investigation of the role of large adaptive displays in user behaviour, this series of studies was carried out to clarify the factors of display use which presented the strongest implications for informed user behaviours. As there were multiple points of interest identified in the "Field Work" (Chapter 4), this display driven approach worked to inform the mechanisms of adaptation to be explored and the methods of observation in drawing together entry and approach and the impact of display behaviours as a warm-up to later investigations.

The investigation is broken down into two distinct trials, with the first comprised of two separate workshops to explore a large number of display factors in user entry and on-going behaviours. This sought to establish critical components of display presentation and limit the number of potential adaptations used. The second trial would then develop these points to inform a more focussed investigation around the role of display adaptation as a prescribed approach.

This chapter describes the design and implementation of each trial, as well as participant selection and the findings in relation to display changes. This will lead to a series of thematic relationships between entry behaviour and the role and impact of layout changes presented as design recommendations, as well as critical factors of use to define the problem space and research area throughout the remainder of the thesis.

5.1 Study Design

As described, the approach is a series of lab-based Wizard-of-Oz trials to assess the themes identified in the field work. The investigation will consist of observations of user interactions, coupled with focus groups and semi-structured group interviews. Finally, a thematic analysis will be employed to identify the critical behaviours to give the broadest consideration of how users influence and are influenced in turn. This will consider three main relationships;

1) How do layout and presentation influence entry and approach behaviour.
2) Factors of layout and presentation change which influence on-going constellations and the impact to user experience.
3) How social organisations of users influence the effect of layout and presentation changes.

5.1.1 Critical considerations

Based on the findings of the Field Work there were several critical factors of MISU interactions and content presentation influencing emergent interactions. These were;

- Entry position and situation of a display – Display situation relative to entry position influencing awareness and approach behaviour. As there is a limited understanding of forms of presentation to on-going use this factor will initially be omitted.
- Role of formations during entry and approach – The formations of users will inform towards locations of approach for shared interaction. Considering how presentation leads to formations of users and the impact of layouts during entry.
- Multiple points of interaction – Discrete points of interaction allow for MISU engagement although these must be considered in the context of on-going use, assessing how multiple content items are presented and utilised by multiple groups.
- Ownership of interactions – Seen as both an active trait of user formation and a passive component in determining on-going use, ownership can influence decision making during approach. Identifying how ownership is established and maintained in on-going use to highlighting boundary creation and curation, and informing the use of content in managing and support approach.

Considering additional points taken form literature;

- Movement of content on a display has been shown to have a leading effect. By considering how formations and ownership are established to points of interaction, this approach will be used to influence user position and awareness during on-going use relative to multiple points of interaction.

Multiple combinations of these factors are evaluated to establish a combined understanding of presentation and layout changes, as well as identifying impacts upon user experience. This will present design recommendations for static and dynamic aspects of display behaviour, and further focus the relationships of entry and approach for MISU interactions.

5.1.2 Locations, Population and Sample

The lab-based trial was carried out at the Mixed Reality Laboratory, in the University of Nottingham Computer Science building. The study consisted of two separate trials with varying avenues of investigation. The first being a sensitising trial, and second a more in depth investigation. Both trials were carried out on a large top projected digital display, of approximately 1.5m in height by 2m in width, placed at a height of 1m from the ground, situating the centre line at a comfortable viewing position.

The first trial was made up of two separate workshops, addressing the interaction of a single group with a wide range of presentation factors. The workshops were run with groups of five and seven participants respectively. All participants were members of the Mixed Reality Lab and experienced HCI researchers. The second trial was a focussed investigation of multiple simultaneous group interactions in relation to layout adaptation, involving four repetitions with groups of seven participants. These participants were selected from the staff and students at the university and had no prior experience of the interaction.

Trials were constructed using Microsoft PowerPoint to create a series of scenarios which participants would engage with and be observed, followed by a feedback session on their experience and reported decision making. Participants were told that the trials were investigating a semi-functional system that was responding to their grouping and movement behaviours. As users entered the interaction space various layout and presentation changes would be applied to the display using pre-defined animations.

Participants entered the display space at the beginning of each trial with their initial entry and approach documented. They would then be observed for around one minute while the layout changes took place, with any points of interest noted. Once the interaction was completed a semi-structured group interview would take place, highlighting any points of interest to identify the awareness, interpretation and decision making of users.

5.1.3 Trial Descriptions

This section describes the design of each trial and the intention in identifying the role and critical aspects of presentation and layout changes.

5.1.3.1 Trial 1

This trial consisted of two separate workshops assessing how individuals perceived aspects of layout change and presentation in relation to their own actions and the actions and requirements of others in the space for between and within group experience.

This trial was carried out in a curtained-off area to give the impression of a private, or semi-private interaction, framed as an exhibition or interaction space. The two workshops considered groups of five and seven members respectively, with the participants in workshop two being divided into smaller groups as required. This provided initial feedback on the three points identified above. The factors investigated and layouts used were;

Workshop 1:

Comprised of eight short interactions lasting around thirty seconds to one minute each, this considered the starting position of content windows and forms of presentation upon group formations. Once at the display the interactions would investigate combinations of the following factors; window duplication, varying distributions of content, varying content types, real time adaptation of content and layouts and clustering of mixed media. The diagrams of the layouts and interaction designs can be found in the Appendix [B1 Layouts]. The eight interactions considered the following points (Table 5-1);

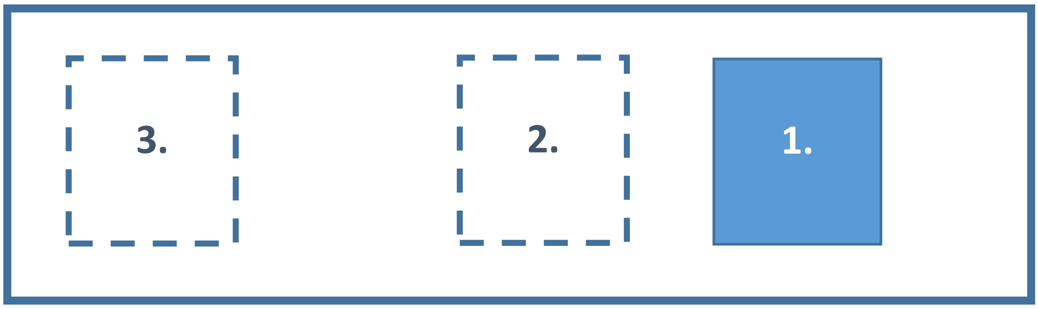
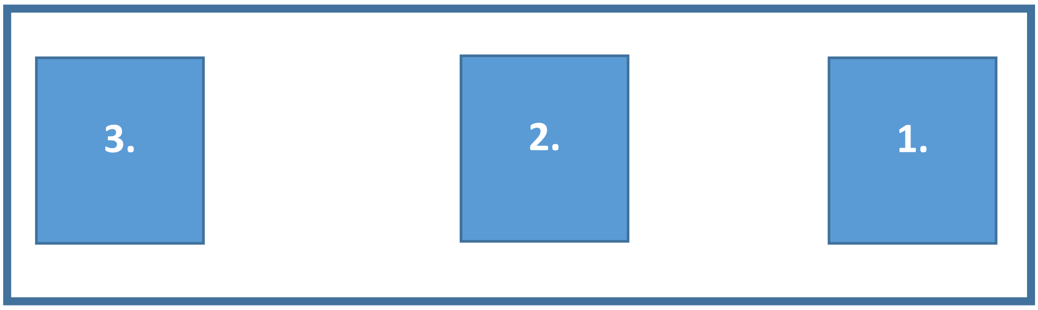
	Initial design	**Expected outcomes**
1.	A single window is shown to the left of centre. After 12 seconds a second window is shown at the right hand end of the display. Both windows are showing the same content.	A group will form around the first window. With the second window shown the group may gain awareness and split, based upon the initial formation and individual preference.
2.	A single window is shown to the left of centre. After 12 seconds a duplicate of that window will move from behind the first to the right of centre. Both windows are showing the same content.	A group will form around the first window. As the second window is shown and moves to the right the group will widen their formation to allow viewing of the second window. As the window stops moving the group can assess how they chose to organise about both points.

3.	A single window is shown to the left of centre. After 18 seconds a second window is shown to the right of centre and both will move away from one another until they are equally spaced across the display. Both windows are showing the same content.	A group will form around the first window. As the second window is shown in the same location it is highly likely to be seen. The longer interaction time may encourage a stronger connection to the first window. The separation of the windows may cause the group to fragment based on starting position.
4.	Two windows are shown equally spaced across the display. Each window will show different content played on a loop.	Both windows clearly show different content and may encourage two distinct formations. The starting position and proximity may allow for a single group with sharing of content between both. This will be dependent on personal choice and the level of group cohesion.
5.	Two windows are shown to the left and right of centre respectively. Each window will show different content played on a loop. The content is much finer detailed requiring a closer approach.	The central position and detailed content will likely cause a close formation to the display. Groups may expect adaptation given the display size and allow space for movement. Individuals will likely select a location based on their preference for content and not group organisation. Users may chare information between windows given their close proximity and group organisation.
6.	A single window is show one third to the left of the display. After 12 seconds this window splits into two showing the same content, and a third window is shown at the right hand end. All windows show the same content.	The group will form about the single window. The window splitting will cause the group to reorganise and explore the display. The formation may spread out to allow for engagement with both windows to the left. Users may break off to investigate the single window to the right if they become aware of it.
7.	A single window is show one third to the right of the display. After 12 seconds this window moves to the right end of the display, with new windows shown at the centre and extreme left of the display. All windows show the same content.	With the initial formation to the right the movement of the adaptation may cause the group to focus more heavily in this direction. The new central window may be noticed causing searching behaviour, with the left most being discovered. The initial formation will determine how windows are discovered and the likelihood of users separating from the group.

8.	A single window is shown one third to the right of the display. After 18 seconds two duplicate windows appear from behind the first and move to the right and left respectively until all three are equally spaced across the right hand end of the display. All windows are showing the same content.	As the group initially forms at the right hand end of the display the adaptation will be clear to all members. As all windows show the same content the formation may open up to allow more comfortable viewing for each individual whilst still maintaining the group interaction with the same content shown.

Table 5-1: Table showing the key factors of the interaction designs for Trial 1 Workshop 1

The interaction windows were kept deliberately small compared to the number of users at around 50 x 90 (cm), with content changing every 6 seconds to encourage group focus. In most cases windows were duplicated for the adaptations as this sought to explore how individuals related window size and content presentation to the group organisation, and the role of windows in providing scaffolding between boundaries within use. One example of these interactions is given below (Figure 5-1);

Study: 1, Workshop: 1, Case: 7

Window (1) will start at Right side/centre. Windows (2 & 3) will be at display Centre and extreme Left side respectively, these will not be visible.

After 2 slides (12 seconds) Window (1.) will transition to Right/right and Windows (2. & 3.) will both become visible.
Expected outcome: As the initial cluster will form around the right-most window this may limit the awareness of new windows forming to the left (due to the size and orientation of the group). The central window may draw attention to the adaptation and encourage searching behaviour. Upon formation of the new windows there will likely be a fragmentation of the initial group, however, it may be that only a small number break away and claim "ownership", particularly window (3.) due to distance.
Figure 5-1: Showing the experimental layout and adaptation of content windows in Study: 1, Workshop: 1, Case: 7 highlighting the expected influence of the layout.

Each of these interactions was carried out once with five users posing as a single group. The user group was asked to enter the space from the rear left corner of the interaction area, approximately 3m from the display. Each case employed a different initial layout to assess impact upon entry and arrival. Once the group had formed an initial formation at the display a combination of window movement and changes in presentation would be applied to assess how these were identified and the impact this would have to the on-going interaction.

Workshop 2:

Comprised of five short interactions lasting up to two minutes each, these considered how several smaller groups interact in response to adaptation and "interactive" system elements. This expanded upon the findings of workshop 1 to consider how ownership and system feedback influence group interactions, with many of the same factors being considered. This trial considered elements of semi-interactive and responsive systems within the group experience with the aim of considering ownership, exploration and learning effects. The diagrams of the layouts and interaction design can be found in the Appendix [B2 Layouts]. The five interactions considered the following points (Table5-2);

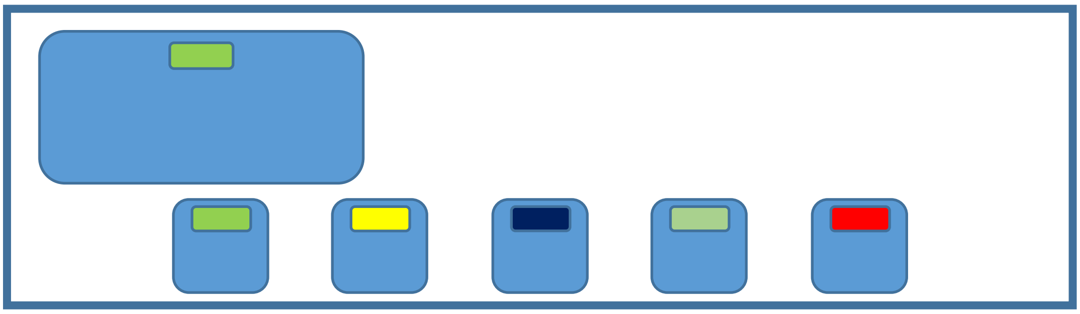
	Initial design	**Expected outcomes**
1.	A single group of (3) enters and is presented with a large content window. A second group of (2) enters causing window one to move left with a second smaller window shown to the right. Window one is removed and a third group of (2) enter with a new window shown to the left. As group one retreat a new fourth window is shown in the centre of the display.	With windows being shown upon entry groups would likely approach the locations they are shown and organize around this point. Windows size was made relative to the group size, so this may give indications as to ownership and territoriality. As windows are removed and new ones shown relative to group entry the ownership of the space and interaction can change dynamically based on awareness.
2.	A single large window is shown in the centre of the display. As the first group of (4) enters a colour co-ordinated (green) vertical window is shown to the left of the main. As the second group of (3) enters a second vertical windows (yellow) is shown to the right. After several seconds the main window splits to the left and right respectively, maintaining the colour coding. At the end of the interaction the windows merge and there is an option to “Share or Split” the windows.	The initial group will likely move to the centre of the space. The inclusion of the second vertical (green) window provides additional information and may cause the group to adjust towards it. The second group entering triggers a second vertical (yellow) window. This may indicate an approach position relative to the first group and act to inform of their arrival. Splitting the windows allows for the groups to establish separate points of organisation. The “Share or Split” option considers how the separate organisations respond to focussing the interaction.
3.	Each group is given a coloured “fiducial” markers to “interact” with the system. As the first group of (3) enters a large window is shown to the left hand end displaying their coloured marker. As the second group (2) enters a second window is shown to the right with an alternate colour. As the third group enters (2) a third window is shown in the middle of the remaining display space. After a delay the first window is removed.	As groups are associating with coloured markers on their content the sense of ownership should be high, with approach being direct and focussed to the point of interaction. Additional adaptations and approach will likely be hidden as groups are focussed on their content. Where content is removed and a different window shown, the coloured indicators should act to identify ownership.

4.	A single window is shown in the centre of the display as a single user approaches. The remaining members (6) are able to enter the space and two additional windows are show to the left and right of the first. These both have (yellow) colour indicators. After a set time the first window is removed and the two separate windows join to create larger window and move to the left. A new third window is shown to the right.	The initial users will have a clear relationship to the first window. As the second group enter they will have to decide where to interact based on the position of the first user. The colour indicator identifies that both windows are owned by the group and are showing the same content. With the adaptation the focal point of ownership will pass in front of the first user causing retreat to the right. The addition of a new window will present them with a landing zone as they move across the display.
5.	A series of "lightbulbs" are shown along the top centre of the display representing four distinct locations across the width of the display. As each group of (2) [2-2-2-1] enters the space a new window will be shown with a highlighted border and the corresponding "lightbulb" will be illuminated to indicate that this is the newest window to be created.	Relating the windows creation to an aspect of feedback should help approaching users to identify an approximate position across the display to approach based on the "lightbulbs" shown along the top edge. As subsequent groups enter the space it will become more difficult to identify points of interaction based on on-going use. With this being a new form of feedback users may relate this to the changes on the display.

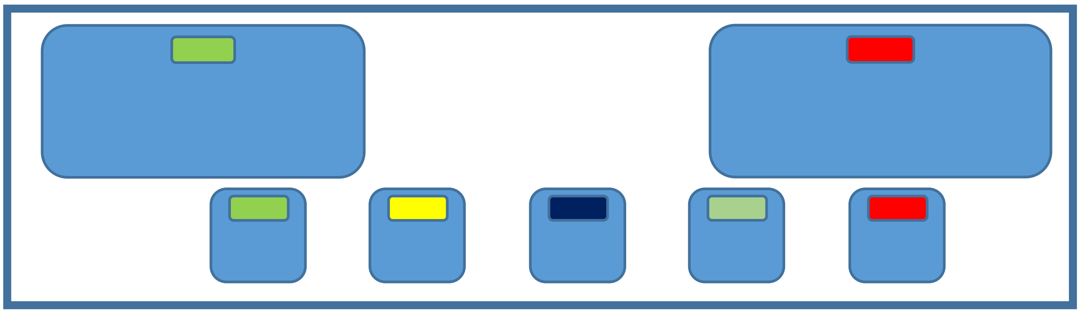
Table 5-2: Table showing the key factors of the interaction designs for Trial 1 Workshop 2

These interactions focused more heavily on how groups gained awareness of the display through adaptation and were able to establish a landing zone and interaction, with adaptation used to inform adjustments in group behaviours and approach via on-going use. As a number of groups are able to interact simultaneously a number of ownership factors are evaluated, such as timing of adaptation, colour markers, and window size and position to group entry. The content shown was also distinct for each group to explore how ownership and focus to windows changes between multiple groups. One example of an adaptation strategy is given below (Figure 5-2);

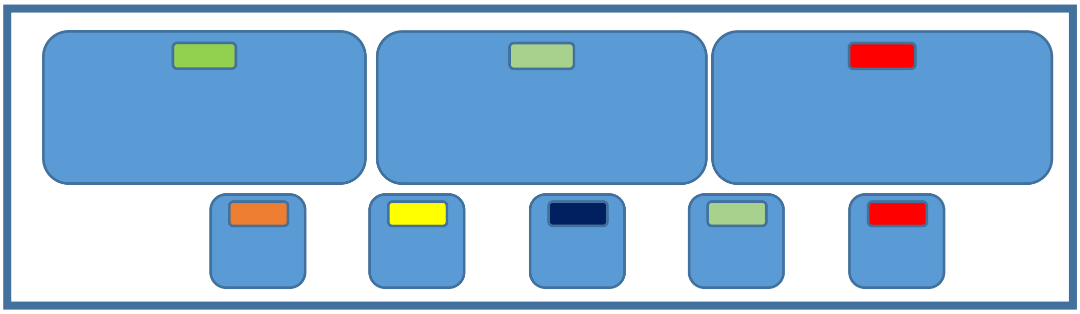
Study: 1, Workshop: 2, Case: 3



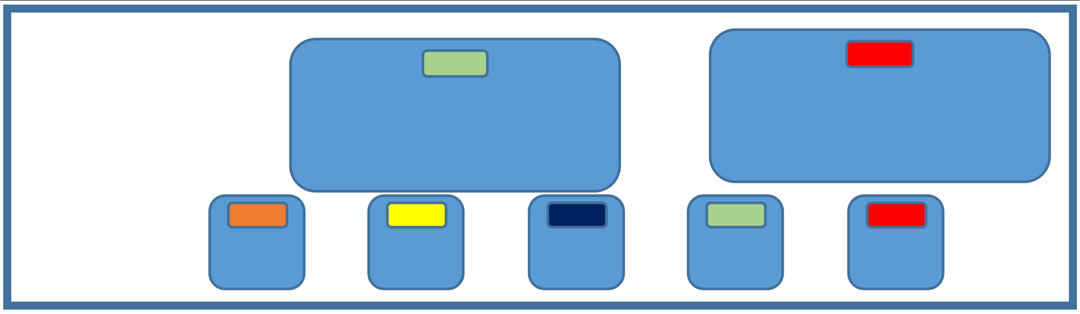
After one slide (6 seconds) a content window will be shown.



After a further 3 slides (18 seconds) a content window will be shown.



After 2 additional slides (12 seconds) an additional content window will be shown.



After a further 3 slides (18 seconds) the first window will be removed and the third window (gray indicator) will be moved towards the available space.

Expected outcome: Users will be split in to three group and handed a "randomized" colour card with fiducial markers. Users will be informed of a Kinect camera underneath the display and encouraged to interact with it. The colours of the cards correspond to the order of the windows in an attemtp to provide ownership of a window as groups enter. The interaciton between user groups should be limited, however, it is possible that the interaciton with the system will overule the interaciton with the content resulting in exploration of the display leading to group interacitons.

Figure 5-2: Showing the experimental layout and adaptation of content windows in Study: 1, Workshop: 2, Case: 3 highlighting the expected influence of the layout.

This is the most complex version of the test cases for Workshop 2, as it relies on users interacting with the mock functional system and reporting on their experience. While this is designed as a group experience, only a single member of the group is given the coloured "interaction card", which are handed out in the same order as the adaptations shown above.

As the diagrams and descriptions in each case are lengthy and do not add significant additional information to the context or the findings they have been omitted.

5.1.3.2 Trial 2

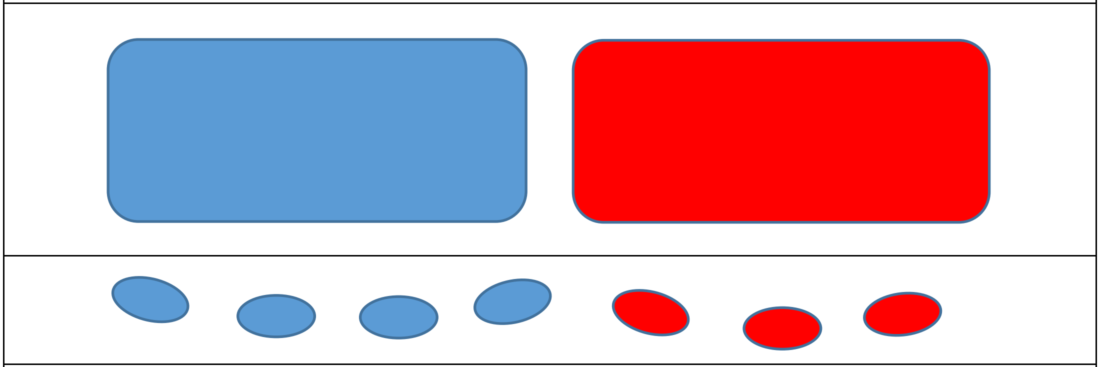
The second iteration was designed based on findings from Trial 1, with aspects of layout and presentation changes that were seen as unnecessary or negative to the experience removed and factors of position and awareness being the main design factors. Presentation of content was simplified to colour coded content windows used to identify group ownership and the scenario was simplified to reduce the number of groups and potential interaction types.

The trial was composed of four separate interactions, lasting one to two minutes, followed by a semi-structured group interview. Each interaction would require participants to be split in to sub-groups of 1, 2, 3, 4, or all members and being issued with a colour (Red, Blue, Green, Purple) based upon the design of the content. Content windows were filled with a sizable body of text with the text size set to encourage approach to between one and two meters distance. Groups were informed they could approach the display once their group colour was shown. The interactions would then be observed followed by semi-structured questioning.

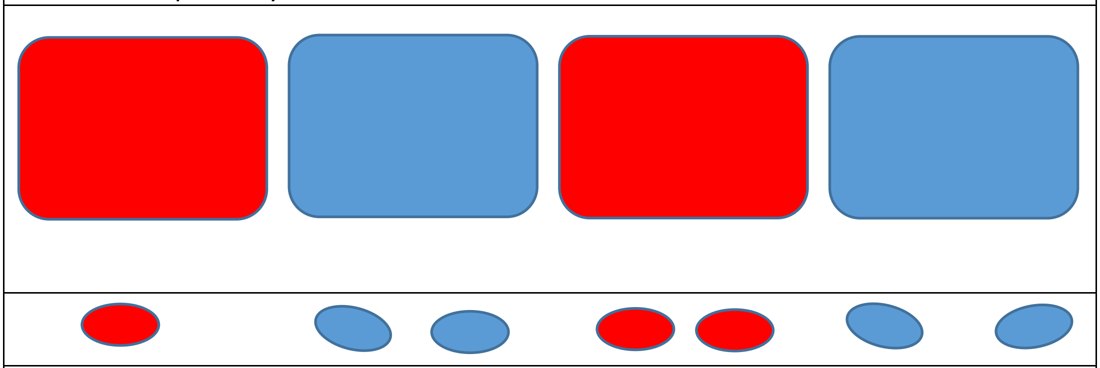
These trials were conducted in an open area of the lab with users having a perpendicular approach to the display from approximately 4m away. The space itself was closed throughout the trial, however, the location encouraged the sense of a public interaction, combined with the separation of participant in to groups to create a sense of public space and competition.

To increase the sense of realism, participants were briefed with a scenario describing a public exhibition space with an extremely large display (>10m width), with the display representing a segment, so encouraging the groups to cluster directly in front of the display and not stand to the sides. The relationship of groups to colours was reinforced to encourage multiple user groups. An examples of the layout changes and rationale can be seen below (Figure 5-3);

User Study: 1, Case: 1



Initially two distinct groups (red / blue) will form at separate windows with (3 / 4) members respectively.



After around 20 seconds an additional red and blue window will form at opposite end of the display, resulting in the on-going windows being reduced in size.

Figure 5-3: Showing the experimental layout and adaptation of content windows in Study: 1, User study: 1, Case: 1 highlighting the expected influence of the layout.

By limiting the number able to interact around each windows, in particular blue, this may encourage changes in formation or the group fragmenting over several windows based on the awareness of members to changes.

This trial will investigate;

- Window Size and Position - Relative size of windows to viewing position
- Density of multiple Groups and Windows - Multiple groups in close proximity will have to manage their position and orientations, likely influencing the awareness.
- Awareness of multiple windows – Occlusion and interaction of groups will influence the overall use and awareness of the display.

This is one example of the test cases, due to brevity the remaining test cases can be found in the Appendix [B3 Layouts].

This trial was run four times with groups of seven participants to establish an initial range of response to each case and the impact of learning and interaction effects throughout. The trial was not run in a between or within approach with additional participants as the aim was to consider the initial response behaviours for a full scale investigation.

5.2 Findings

This section will now consider how the findings address the three main factors of user and display relationships;

1) How do layout and presentation influence entry and approach behaviour.
2) What are the factors of layout and presentation change which influence on-going constellations of users and how are these perceived in the user experience.
3) How social organisations of users influence the effect of layout and presentation changes.

As these sensitising trials are iterative in their nature the two trials will be presented separately, with the critical findings reported. The findings are not given in full due to the volume of information captured, instead, a thematic representation is given to describe the role of display changes along with design recommendations in the use of presentation and layout as an aspect of user experience. The findings and summary of each of the trials can be found in the Appendix [B1 B2 B3 Transcripts and Summary] respectively.

5.2.1 Trial 1 – General considerations of display and presentation

Trial 1 sought to bridge the gap in the observed behaviours form the Field Work and sensitise to the potential presentation and layout changes of a digital display in a lab-based setting. Workshop 1 considered how a single group would respond to a wide array of display factors, whilst workshop 2 considered how multiple smaller groups would interact with informed aspects of presentation.

Trial 1 proved to have significant issues in both design and implementation in terms of user response. Poor choice in both content selection and presentation, specifically font size, resulted in users standing back from the display and separating from their intended content windows. With limited direct approach to the display and a reduced level of ownership, the addition of new windows and adaptations had little effect on group organisation or response. In most cases additional approach by later groups was hampered or directly prevented by the positioning of earlier groups, and tendencies for individuals or groups to separate from their content windows to explore alternative items of content shown. Both are now presented below;

Trial 1: Workshop 1:

This workshop focussed on the behaviour of a single large group when interacting with a range of adaptations and content types, including images, captions, blocks of text and fine detail images ("Where's Walley"). As such the findings are distributed between aspects of group behaviour, individual behaviour, factors of the adaptation, layout and presentation, and design factors. This workshop initially considered; 1) a private interaction for a single group in an enclosed space, 2) a single group response and individual behaviours, and 3) individual position and awareness towards adaptation and the impact to the group experience.

While this workshop did not allow for exploration of layout and presentation factors directly in the way it had been designed, there were multiple points of interest identified in why these interactions did not work. Taken across all eight interactions there were several themes identified in the approach and engagement behaviours of the group, as well as specific aspects around the presentation and layout of content which are described below;

Themes in Behaviours:

There were four distinct behaviours identified in the workshop; casual approach, focussed approach, adjustment and retreat. These behaviours were related to factors of the display;

Casual approach: Seen where the group would hang back from the display to view content and adaptations. The group is loosely packed and all are able to view the full display as a single line. This was seen in several scenarios, where either content presentation did not require a direct focussed approach, or where adaptation resulted in a large separation of windows, resulting in group retreat. When seen in the retreat case, this strategy was thought to minimise effort in the task instead of moving between multiple focused interactions.

The limited approach towards the display results in a large cluster of users and so the impact of adaptation is mitigated. There is no need for users to move in response to layout changes as they are able to view all items of content from the current position. This results in user attention being split across all items and no one focal point or shared experience being achieved. The on-going distribution of users prevents approach from behind, and layout or presentation changes have no clear relationship to actions or behaviours so do little to influence the group organisation or points of interaction.

Focussed approach: Seen where the full group would approach close to the display and form a tightly packed cluster, occasionally in a semi-circle or two row formation. This was seen in several scenarios, including;

- High detail presentation requiring users to be extremely close to read content.
- Blocked line of sight where a single user approached the display blocking content so requiring the remainder of the group to approach.
- Multiple content windows in relatively close proximity resulting in an optimal viewing position closer to the display for clear line of sight to avoiding blocking one-another's view.

The result of these tight formations would lead to a reduced awareness of the overall display and adaptation, but would leave areas free for separate content to be shown. Adaptations could lead to the adjustment and retreat behaviours where the adaptation expanded the point of interaction to require a wider viewing field. Where adaptation was apparent in the periphery of the cluster, the group would adjust their positions to allow more favourable position and line of sight within the group. Alternatively, where adaptation was more widespread the cluster would retreat, effectively moving in to the casual approach position.

Adjustment: Seen when the group was engaging with a single item of content, either upon arrival to the display, or during adaptation. In both cases this would be in the focussed approach state and was seen as a supportive action to aid in all user's experience. This was seen in the group switching from a two row interaction to a semi-circle where adaptation presented a window at the periphery of the group. In both cases the group was able to form a flatter, more focussed semi-circle around the point of interaction that facilitated a cohesive experience. Adjustments were seen to stem from an awareness of others viewing positions and desire to maintain a stable formation, where individual users were aware this would mitigate impact upon their interaction.

Retreat: Seen in examples of focussed approach where adaptation was identified but not clearly visible from within the group. Where adaptation moved content windows away from the groups focussed position, the response was to fall back from the display to attain a wider viewing angle. This appeared to be an emergent behaviour as adaptations were not identified by the majority of the group, instead local responses to adaptation would draw attention and result in group retreat. This would lead to adjustment from individual(s) who performed the local action to bring their position more in-keeping with the wider group, allowing for line of sight and personal space.

Individual Behaviours:

There were several aspects of individual behaviour outside of the group interactions which influenced the overall engagement with the display and adaptations. These include;

- Direct approach to the single content window, blocking line of sight for all other users. This resulted in group clustering leading to shoulder surfing and later adjustment towards line formation to support all users. When adaptation took place limited numbers of individual users were able to identify the change and respond, with the group retreating to engage.
- High density scenarios would limit the ability of users to adjust to support the wider group and prevent line of sight to those at extreme viewing positions. Users who were unable to view content or had extremely limited views had a greater awareness in identifying distributed content and moving away from the cluster.
- Individuals would search between windows to identify examples of repetition or sharing interesting content between windows. This became more apparent in later trials where users had begun to identify there were multiple items of content being presented in the trial and that much was being missed. This was only seen in casual approach or loose clusters where multiple windows were visible to the group, and not when the group had split in to sub groups.

Adaptation, Layout and Presentation:

There were several points of display factors leading to changes in user behaviours. These are difficult to directly identify as there are multiple relationships between several of these elements within scenarios. The following examples show;

- Presentation of content directly affected the viewing position and approach of the group. Where content was either images or large font text, the group would only move forward as much as necessary to engage as there was no benefit to additional movement as this introduced issues of negotiation.
- Where layout placed windows in close proximity the group would cluster around multiple windows and attempt to interact. Duplication of content did not support a grouping scenario, with users at edges identifying a single window and those in the centre attempting to view both. Instead, factors of presentation would influence the tone of the experience, either by the content "being hammered home" when showing the same images, or missed experiences when there were multiple items of significant text and users not being able to engage with all of it.
- Learning effects between experiences led to short term decision making about the nature of the adaptation or presentation of information. Several users reported making assumptions about content windows based on earlier observations, however, this cannot be clearly identified in this study, it did lead to positive experiences where the system responded unexpectedly or in a supportive manner

to the current use case, either for a better group viewing position, or in supporting those in poor viewing positions by creating a new window.

- The use of multiple windows to present supporting information was not thought of as helpful without additional information. As with duplication, additional windows were found to be distracting and user did not know where to focus or how to engage. Users reported quickly identifying the windows by shape and size and then ignoring the ones not directly useful, i.e. smaller windows containing additional information, unless local to the individual and there being sufficient time to shift focus.
- Initial layout and presentation would directly affect entry behaviour and group formation. Subsequent timing and position of adaptation were then relative to these formations and would act to either reinforce or separate the group based on current individual interactions. The number of windows and presentation of content shown to a single stable group would have a strong influence on the tone of the user experience, with oversaturation of both content and requirements for adjustment leading to an implied pressure.

5.2.1.1 Design Factors

Factors specifically relating to the design of content and interactions influenced overall behaviours and user experience. These were;

- Duplication and quick changes in presentation introduced a pressured or forced feeling to users. This could be related to the timing of changes, but also presentation and layout leading to an overwhelming or crowded appearance.
- Windows in close proximity were distracting and it was not clear what was being shown without several minutes of interaction and repetition of content. Multiple windows showing high volumes of content were distracting from one another, although this did lead to conversation and sharing of information between windows.
- Learning effects led users to ignore or assume the nature of multiple windows without clear feedback on the nature of the content or interaction. User feedback or control would lead to several areas of investigation, such as; nature of the content, voting for changing pages, pausing or separating multiple windows.

These findings present a complex and wide ranging number of factors in group interactions and the role of the display in decision making. There are several key insights which are notable relating to the overall group response to forms of adaptation and presentation;

- Individual behaviours can immediately impact upon group dynamics and emergent behaviours, but also work outside of the collective group actions to introduce new aspects of spatial decision making. As no individual maintains allegiance to the group's actions or engagement, individual behaviours should be considered within the wider experience of the group to include viewing position, presentation and layout as well as potential separation. The engagement formation is a homogenized response of all user engagements and is ultimately influenced by the impact upon and actions of each user. As such, any action upon or action by any single user should be considered and understood when utilising adaptation, presentation or layouts of the display with an informed knowledge of the user experience.
- Adaptation, presentation and layout all influence group and individual interactions in an independent and interconnected manner. The relationships between these factors is unclear yet both simple and complex in its nature. With examples of direct

impact upon behaviours and subtle influences to experience, a more controlled and informed method of investigation is required to unpick these factors.

This initial workshop set out to assess how a wide range of layout, presentation and adaptation factors might interact and influence the entry, approach and unfolding interaction of a single group. These factors were then incorporated in the design process for workshop 2 to present a more complete picture around on-going factors to the investigation of adaptive displays with multiple smaller groups. The findings from Workshop 2 are now presented;

Trial 1: Workshop 2 This workshop considered the interactions of multiple small groups of users with adaptive layouts and presentation, as well as an "interactive Wizard-of-Oz" system. This sought to address the role of individual behaviours and ad-hoc groupings, as well as perceptions of ownership, interactivity and sharing of content windows. This workshop was composed of five specifically designed interactions to consider three factors;

1) Private shared interaction space.

2) Multiple smaller groups interacting with shared and private content.

3) Interaction between individuals and within groups.

In a similar fashion to workshop 1 there were significant issues around content selection and presentation throughout the test cases resulting in casual approach by one or all groups within the interactions. While the content had been altered to reflect the issues found in workshop 1, issues was mainly due to the workshop being described as "interacting with a semi-functional system", leading users to quickly break with engagement where a system-led response was not forthcoming. While the user groups did not show focussed or direct approach to the display in the majority of cases, there were clear implications of the role of layout and adaptation within the interactions. Descriptions of users' behaviours can be found in the Appendix [B2 Transcripts and Summary], with key findings presented below;

- Content appearing as groups enter the space is considered normal behaviour for an active system and gives an immediate sense of ownership. Approach and organisation are then relative to the presentation of the content and available space. There is no consideration of other people using the space even when it is known that additional groups will be entering.
- During entry the organisation and formation of a group will be relative to the display size and available space. The group will spread out to allow each member to have a comfortable viewing position. Group cohesion is found in relation to the focal point and not the group structure. There is opportunity for a shared experience without the need to be tightly clustered or having direct approach to the display.
- Where adaptations took place during an on-going interaction there needed to be a social awareness of any new group entering for there to be an understanding of how the adaptation was related. Where adaptations took place away from the entry position this meaning was lost during on-going interaction as there was no social requirement to respond, the new group were not at the point of adaptation and so the adaptation was perceived as a feature of the display, resulting in no change to the initial interaction behaviour.

- In forming an awareness of display adaptation and potential landing zones during entry and approach, considerations of on-going interactions and social boundaries presents a clear separation in potential action and resultant behaviour.
- A lack of responsive window behaviour or mapping to a groups' behaviour or organisation presented a significant stumbling block in forming a clear relationship to content window behaviour. Where content is presented in a scaffolded manner, social organisations dictate how the space is utilised, with there being no clear relationship to actions of the display indicating aspects of social-spatial behaviour, even when there is an awareness or understanding of potential ownership, entry, or approach of another group.
- Adaptation during entry around on-going interactions were identified as related to entry, however, there were stronger considerations of social organisation and ownership for windows already displayed. New groups would actively avoid approach if they thought this would impact upon another interaction, even when there was a clear link to adaptation, as there was a desire to avoid social pressures.
- High degrees of detail and dense content presentation saw very high levels of focussed approach and engagement. Individual interaction with content (fiducial markers to select content) encouraged either very tight coupling or complete disinterest in content selection, the experience was either tailored to the users or it was not. This transferred over to individuals in groups wanting to be able to interact with the content more directly on behalf of the group. Interaction with content between groups was extremely poor as no one individual wanted to make the decision for both groups.
- Any break in interest with content would see retreat and exploration of the display, resulting in groups moving to other items of content, preventing further approach by later groups. Tighter coupling or mapping of content to groups' behaviours would help situate the group focal point, but must also consider the nature of group behaviour relative to on-going interactions. Recovery of an uninterested group can take place, but should not impact upon on-going interaction boundaries.
- With learned behaviour, or an awareness of likely potential use of the space, approach behaviour is reduced where there is no clear scaffolding of content presentation to the display space. Presenting content in the middle of the display presented an awareness of the remaining display and interaction space and reduced the likelihood of focussed approach.
- Where there is sufficient space and line-of-sight, multiple points of interaction can be presented, understood and engaged with during entry, however, this will consider any on-going interactions as it applies social pressures.
- Groups would wait their turn to interact, but would also view other available content. When it was their turn to interact with the same content they would quickly become bored and retreat to explore the remainder of the display.
- Utilising adaptation during entry can inform the use of space and approach, but can also introduce significant drawbacks in the level of engagement during interaction where the emergent formations do not best support approach and natural organisation about landing zones to post adaptation scaffolded content.
- Considerations of how the display should be laid out once landing is achieved would significantly improve the overall user experience towards adaptation and on-going use. Adaptations should work to best support natural emergent social organisation.

- Applying adaptation post landing must be done in a way which supports on-going interactions. Any on-going interactions must maintain a connection or mapping to the display to prevent a break in the interaction, and any adaptation of the display relative to another group must have a clear relationship of social ownership to prevent confounding actions.

While the groupings were prescribed for each test case, there were several limitations in how this presented a true representation of multi-group interactions. A limitation was found in changing the group compositions between trials, with some members being more familiar with others and so preferring to be a part of certain group, or having little allegiance to a prescribed group. This lead to individuals breaking group cohesion to explore the display during trials when content was not to their liking.

Interestingly, this combination behaviour of semi-structured groups and familiar individuals within the interaction space lead to several factors of display use which had not been considered;

- Content selection via system interaction was a very powerful mechanism to initially gain a focused interaction and ownership, although all users reported they would have liked to have had the choice and not had content prescribed which resulted in retreat in several cases.
- Content selection would have been much better supported where there was a system response to support ad-hoc group formation, such that content would become more apparent and accessible as more people engaged with it.
- Sharing multiple windows between groups was not clearly understood initially, however, once it was noticed that content was looping there was a tendency to share interactions between windows and this became the focus of the experience, with groups being forgotten or ignored as shared content became more engaging for multiple groups.
- If a display is responding to user behaviours or giving a personalised interaction then levels of feedback must be much higher and more tightly coupled to groups, otherwise the display will be used as an ambient object, with social organisation driving interaction.
- Groups should not be prescribed for the interaction. An interactive or responsive system makes sense where there is a coupling to behaviour, with groups forming relative to the system response. Any behaviour of the system must meet expectations of the group, otherwise the system has a negative impact.
- It was unclear why a large display did not show a single piece of content. There was no need to have multiple windows when users were able to form and interact with multiple items of content, particularly in cases of duplication, which reduced their experience of interaction.

These points are now considered as design recommendations in the use of multi-group interactions for large digital displays.

5.2.1.2 Design Recommendations

Trial 1 has now considered a wide ranging number of factors of display layout, presentation and adaptation in both single and multiple group scenarios. The problem space has proven to be extremely complex, with large numbers of potential variations in each aspect considered, yet there are specific components of system behaviour and user responses and themes which can be more clearly related. These investigations have identified multiple factors of user experience which do not support effective display use in both situations, which presents a more focussed area of design and investigation in future studies.

Describing the theme of the workshops as a personalised interactive experience was a poor choice that resulted in participants focussing on the technical function of the system instead of their role as groups interacting. The "Wizard of Oz" style of study does give some interesting effects, however, a more descriptive style of interaction focussed on user behaviours would likely give better results.

When creating content windows and personalised experiences it is key to highlight ownership to prevent confusion, the same should be done at the end of content delivery to prevent a sudden break in the interaction. If users are going to invest in an experience then it must last from the beginning to the end of the interaction, or the design of the study must further focus on the influence of adaptation and feedback as mechanisms to support changes in behaviour within and around simultaneous interactions.

The factors of layout and presentation in creating new windows, as well as feedback to users will have the most significant impact during entry and approach behaviour. There is no reason to approach the display if content can be read from distance, which has a negative impact upon initial formation and effectiveness of adaptation and organisation. Initial layouts and timing of adaptations should also be considered, as meanings and ownership relationships can be missed and false positives or incorrect reinforcement applied.

The separation of groups from the display was seen to have a prominent impact upon new groups entering as there was a strong desire not to interrupt or intrude upon an on-going interaction. Where current groups stood in the centre of the space or in open formations, this would indicate a wider ownership of content and the display, leaving new users taking a less optimal viewing position where they had identified ownership or a desire to approach. This leads to wider confusion as adaptation continues with no clear relationship to use.

When influencing a group interaction, the use of adaptation can be effective to cause movement but there should be; a clear social reason for causing the adaptation or feedback from the display to encourage following behaviour, or the adaptation should take place when users are deeply engaged to cause a "reflexive" response. Either way, the adaptation must be linked to the group either through ownership or in relation to entry or approach which can be identified by users to give a "personal" interaction and improve user experience.

Local organisation of users appears to be the major driving factor of awareness and influence of adaptation, specifically personal space and line of sight between users. This is particularly the case where users are clustered in the centre of the space with no clear relationship to windows or adaptations to inform or support movement, leading to confusion and possible separation of an on-going group when adaptation takes place. Contrary to this, local awareness of adaptation by external group members tends to have the opposite effect, where new ownership and interaction requirement cause social organisation behaviours to kick-in, resulting in shared spaces and social phenomena, such as line formations and localised F-formations in preserving interactions.

5.2.1.3 Summary

- Presentation must be designed to encourage a closer viewing position, this accounts for font size and the volume of text.
- The initial layout will influence where users approach. This should consider where new groups are expected to go and close proximity between new windows should be avoided to prevent confounding on-going use.
- Ownership of windows must be explicit for groups to begin to understand the nature of adaptations and window interactions.
- Adaptation around groups should consider the periphery of the group and likely awareness of all members to external users that the adaptation is aimed at attracting. Localised interactions can influence the wider group formation and a clear relationship to a new groups' entry, or feedback from the display indicating a required response will support the optimum outcome.
- Studies should be designed with a clear focus on the technology and types of interaction between groups and windows. This should also consider the scenario in which the interaction is emulating.
- The content should be applicable to users and be engaging enough to maintain focus throughout the interaction, although complex adaptations and display feedback could also be considered to evaluate user interpretation and overall effectiveness.

5.2.2 Trial 2 – Focussed consideration of layout changes

Accounting for the findings and design recommendations of the previous trial relating to entry and interaction, this investigation considered the interactions of multiple small groups to adaptations and how these inform and provide feedback during close proximity and high focus. This was achieved by setting a low font size to encourage approach and using only text based content to maintain a lengthy task based interaction. The trial will consider adaptations with imposed group ownership, testing the issue of multiple window presentation in the previous trial. This will further investigate how group formation and individual position affect awareness and response to adaptation.

This trial consisted of four interaction cases, with four repetitions of 7 participants each with no prior experience of the study. A simplified version of each case is presented below, with a discussion of key findings and themes. As this trial considers significantly fewer factors a more cursory thematic analysis is presented;

Case 1: Participants were split in to two groups of three and four respectively (red and blue), with the first entering the space, quickly followed by the second, with two respective windows shown at one third spacing and slightly under one third width of the display. After users were half way through reading their content the layout was adapted to shrink the two initial windows and introduce two further windows, such that all were staggered red, blue, red, blue, equally sized and spaced across the display. This sought to identify how groups would gain awareness and manage interactions both between and within the groups.

Across the four repetitions the approach behaviour was generally similar in nature. After initial approach there would be a short negotiation between the groups that was quickly resolved to utilise the width of the display as a single line formation and allow access to each window, with each sub-group aligned to their respective windows. After the adaptation there were several behaviours identified;

1) Tightly clustered with deep engagement to content – High Focus, Low Awareness - Very unlikely to move or respond to change.
2) Looser cluster showing engagement but removed from the display – Mixture of Focus and Awareness – Observant to local changes
3) Not engaged with the content – Aware of the situation – Response is relative to local changes by other users

Between these behaviours there was no immediate response from any individual as each user continued to read their content and remained in a large cluster in the centre. Users showing behaviours 1) were generally those closest to the display showing no interest to change and were task orientated. Behaviours 2) and 3) identified the additional windows, but only behaviour 3) reported assessing the entire display and the overall change. This was not limited by position to the centre or edge of the initial formation, but instead was attributed to subjective interest in the change.

As users in each group would finish reading they would move towards the secondary window, and the weight of the formation would shift to an end of the display. This asynchronous task completion led to fragmentation in group cohesion and resulted in on-going users adjusting further from the centre to allow space due to social pressures. This was limited by several users maintaining their position and angle to their content (Figure 5-4).

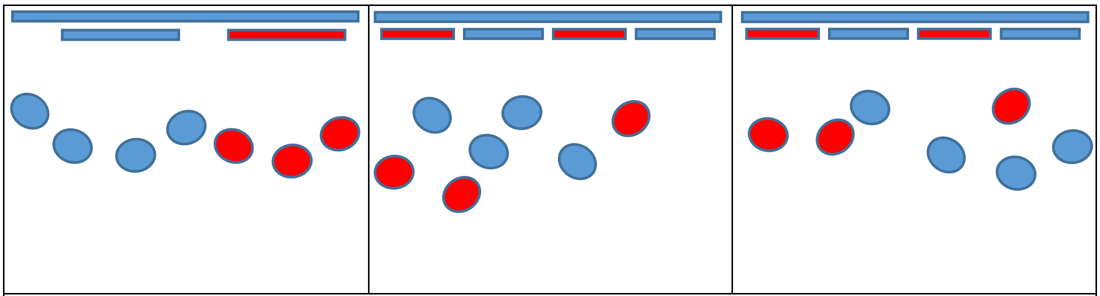


Figure 5-4: Showing movement in respond to the layout change in Trial 2 Case 1.

As edge clustering on a respective side continued members of the slower reading group shifted towards the centre to allow line of sight. As this blocked further approach towards the secondary window any remaining users would be seen to move behind the central cluster and form around their new respective edge of the display. When this occurred all users adjusting position maintained space and line of sight for those at the display, but this posed a significant pressure to finish reading and move as a new interaction was forming around that point. While there was little to no sense of group cohesion, the knowledge that other members had moved to a new window encouraged a change in behaviour to follow suit.

Throughout these interactions the resulting decisions of all participants was seen to impact upon one another and required constant re-evaluation from each member in a dynamic process, whether this was subtle adjustment between two or more individuals, or more out right behaviours in moving around the display.

With no clear requirements from either group to respond to the initial adaptation, as there were no additional users given the design of the study, the respective group clusters did not adjust their formation or local density. As formations began to disperse and user explored the display, ownership of the new windows became a factor and on-going users would adjust to allow line of sight. The issue of densely packed windows previously seen being adopted by a loose formation was mitigated through clear ownership, however, this then applied a social force to on-going interactions when window became in use, although the formations at these windows was removed, the window was present and so had an impact.

Considerations:

- Adaptations affect individuals within the group in different ways, but may not have a direct impact upon the formation. There were some small adjustments seen as adaptation took place, but these did little to effect any wider change.
- A local adaptation suggested a potential wider change and encouraged degrees of awareness, but had no bearing on immediate decision making. There was no requirement to move or respond and so interaction continued.
- Users closer to the display exhibit lower awareness, either through their decision to approach directly, or due to orientation and limited line of sight. Those with greater awareness of layout changes may adjust slightly which can be identified locally by the group, however, without a social cue or need to respond there is limited impact due to the adaptation.
- Peripheral changes of new windows to an interaction have limited impact when in or out ownership is established until there is a clear social implication of the window becoming actively used. This then introduces significant social boundaries.

Case 2: Participants were split in to two groups, blue and non-committed, with five and two members respectively. The two member group were informed they were free to interact with any content they chose. The group of five would be able to enter and have a large blue window in the centre of the display which would be adjusted to the right as the second group entered, allowing a smaller second window to be shown on the left with a large gap between the two. After several moments the second window would adjust its size so both windows were approximately the same size, with the gap between maintained. This investigated concepts of ownership and adaptation between the groups where separation ensured the new windows was not immediately apparent when adaptation took place.

This trial saw two distinct patterns of behaviour related to initial engagement; with a large loose cluster leading to a wider group awareness and response to change, and direct approach and higher focus requiring localised adjustment based on individual position and social awareness. As only one group was initially interacting at the display the adaptation indicated approach of the second, however, the separation between the two windows did not immediately indicate the proximity of the approach position.

While there were two observed outcomes, the casual approach exhibited was the same, with only the direct approach of a single user being different. This direct approach caused the remainder of the group to form a tighter cluster at the centre of the display. Where the initial adaptation took place there was a general movement to the right following the window.

The looser cluster allowed for a general awareness of the new window and through a small amount of adjustment and changes in orientation the second group were easily able to approach the display. In the tighter cluster users re-orientated to the right but did not move significantly, this left the new window unseen by those left most members and so the approach of the new group was not identified. As the second group adopted a shoulder surfing, or turn-taking position they were noticed and those who were blocking line of sight moved to the rear of their group (Figure 5-5).

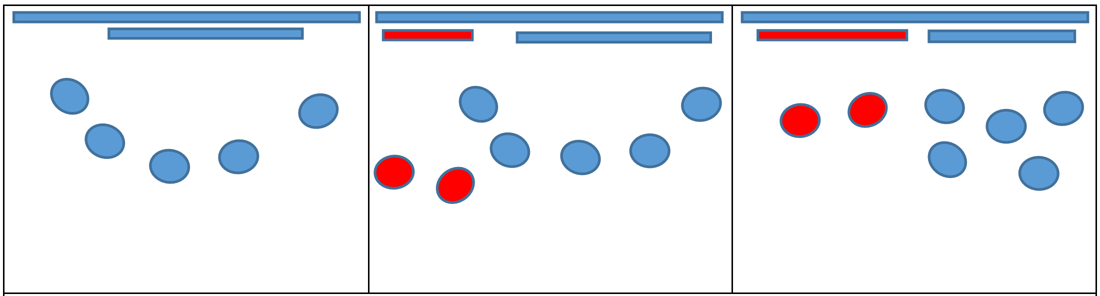


Figure 5-5: Showing movement in respond to the layout change in Trial 2 Case 2.

With the second adaptation there were mixed responses. The majority of participants did not move as they were able to view both windows from their current position, however, the secondary effect was that the shrinking of the first window potentially signifying removal. This resulted in several members of the first group crowding to engage with the content.

As this trial focussed more heavily on the group interactions individual behaviours are less pronounced as groups tended to move together, however, some of the more interesting points of individual behaviours included;

- A dominant member approaching the display and claiming a location for interaction leading to tight clustering.
- A passive member not adjusting with the group and not noticing a new group approaching – as they became aware they moved behind the interaction area and returned to their group.
- Minimal movement from central users in front of the adaptation – the preference was to re-orientate resulting in the remainder of the group moving behind and around this position.

While individual behaviours had less impact there were still indications of the effects. More passive members would approach the interaction cautiously and prefer to stand back, while dominance was seen in how movement and positioning came about during adaptation, requiring second row users to move around and towards the display after the second adaptation. These behaviours were distributed within the larger group and would influence local responses and adjustment based on perceived ownership of space, with dominant responses at the window boundary directly affecting the final formation of both groups.

Considerations:

- The formation of the cluster directly affected the ability for the group to identify the new window due to the separation. Those immediately next to the adaptation were least able to identify the change, and so were unaware of the need to move or accommodate new users.
- Groups present an inverse response to adaptation, with those nearest the adaptation edge least likely to identify the reason for change, and those furthest

away possessing greater awareness due to orientation. Instead it is the resultant social organisation which drives adjustment and not the change in layout unless it is significant and there is a physical need.

- Movement of the window encouraged movement of users regardless of awareness of a new window or approaching group, however, this was limited to the minimum requirement given the initial loose formation.
- Users to the extreme right of the first group had a greater awareness of adaptation and the new group, but had the lowest reason to respond to the adaptation, although were seen to adjusted as users within their group were displaced.
- Dominant changes in orientation to window movement helped maintain individual interaction but did not support the wider group, where small adjustments by all users may have been more effective in supporting the on-going interaction.
- Dominant re-orientation resulted in largely ignoring adaptation boundaries for new group approach, leaving the minimum space available to influence both formations.

Case 3: Participants were split in to three groups, two of three members (red and blue) and a single participants (green). At the begging of the interaction both red and blue groups were free to approach with their windows occupying approximately half of the display each, blue being to the left. After several moments these windows shrank and shifted to the right with a third (green) window shown on the left hand end, each window being the same size and evenly distributed. After several more seconds the red window (right hand end) was shrunk further and a second red window of equal size was introduced to the left hand end. This sought to identify how groups perceived new windows in relation to approaching groups and ownership of space, and on-going adaptation.

This trial had a distinct pattern of behaviour which may be explained by the density of groups and the reduced space after adaptation. Unlike the previous trial where local compromises could be found between groups to limit overall movement, the clear translation resulted in a significant response as it was understood that a new group would require the space. This was partially linked with learning effects relating adaptation with new windows as users had not reported a direct connection with the windows other than ownership up until this point.

While negotiation between groups was amicable, the flanking of the blue window in the centre resulted in the group becoming compressed and stepping back from the display to form rows. This was generally the user to the left of the group where the window had retreated away from their position and a new window appeared, so introducing a local social pressure to move. Where windows were flanked and subsequently shrunk there were small adjustments from the group, but these were tentative and users reported awareness of these windows but no intention of moving unless there was somebody there interacting. This feeling was reported by most all users (Figure 5-6).

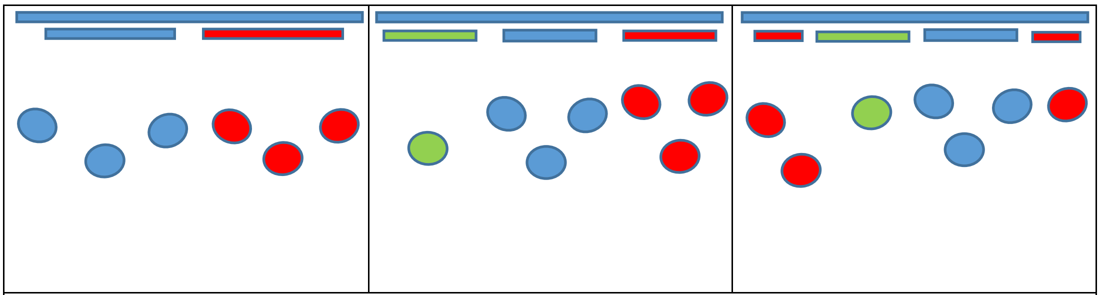


Figure 5-6: Showing multiple group response to new windows and right shift adaptation in Trial 2 Case 3.

With the use of multiple adaptations groups were continually required to adjust and the experience of most was affected. While adjusting did not bother most users, it was clear that focus on the content was affected and users would switch to consider a wider awareness of their local space. While focus was reduced, there was still a clear relationship of moving windows to the overall group behaviour and less of an impact from individual actions and decision. Instead each group would move along the length of the display as each new window was appearing to be occupied. This behaviour was pronounced further by the second adaptation, with the blue and green users moving towards the red window. This caused many of the red users to separate from the window and explore the display.

The more pronounced individual behaviours came from those who adopted a removed position either before or due to adaptation as a response or aversion to high density in the centre. The removed position allowed much wider freedom to select content and viewing position and did not require constant movement relating to adaptation, this led to several individuals switching between items of content and making pronounced moves across the display. High density reduced the impact of dominant users, apart from during entry, as bulk users movement required them to move with the flow of the crowd.

The red and removed users reported enjoying the split in red content as it gave a sense of exploration, however, other members of the red group along with those who stayed at the centre of the display were less happy as they felt they should stay in their location to avoid interruptions and having to move, wanting to engage with the content.

Considerations:

- New windows had a larger impact to on-going groups to move, however, the combination of movement and learning was a cause for the large movement seen.
- Adaptation of windows caused movement of the group and was seen to place pressure on the left most users to move along with the window or to retreat from the display and form behind their initial group.
- The second adaptation encouraged a greater response and appeared to push the initial red group from the end of the display. While several users did stay at the location this was attributed to personal preference.
- There is a physical and social limit to the amount of adaptation which can be applied. Where users are no longer able to maintain or offer personal space they will retreat.

Case 4: Participants were formed in to a single group and shown a single large window. At two separate points additional windows would appear on either side of the main windows, causing it to shrink. These would be coloured for dummy groups (purple and green, who were not present) with the windows containing no content. This aimed to identify how a large group might respond to adaptation where there was no social pressure to interact, by enforcing the concept of window ownership and approach, but also putting emphasis on the user experience related to adaptation.

It was universally felt that multiple groups approaching an on-going interaction was a negative impact upon experience. Comments suggested that these groups were of approximately the same size as the group of participants considering the size of windows, with the central window being clearly bigger than both new windows shown. This may have been related to the design of the previous trials, with the majority of groups being approximately the same size, leading the group to assume any new group was similar in size to their own. It may also be the case that the group felt that if they were having to be moved it was due to an equally large group, and so equal social need for the adaptation.

This idea of “compression” of the group initially stemmed from adjustment by those at extreme wide positions during the first adaptation, which had a small propagation effect but did not affect many members, however, the approach from the second side was significant. As the middle of the group had already adjusted, this left little space for inwards movement, resulting in moving behind the group and this being clearly visible to all members.

For participants at the rear of the group there was no need to adjust position throughout. The removed starting position required only minimal response to large adaptations without affecting viewing. This was a product of personal preference and seen consistently from some members across each trial, either in approach or response to adaptation (Figure 5-7).

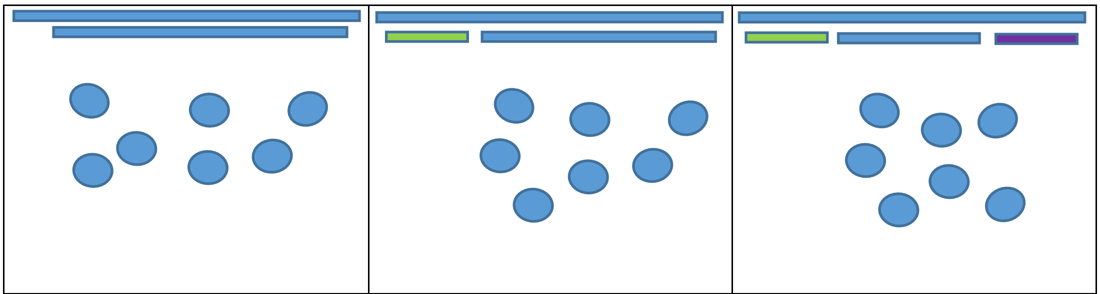


Figure 5-7: Showing a single large group response to adaptation in Trial 2 Case 4.

As this was a large group the effects of dominant behaviours were diminished, however, the impact due to starting position and personal preference were significantly more evident. The adaptations at the edges of the group immediately forced several members to adjust their position to support the wider group interaction, as was noted when several participants reported wanting to “protect the group” and try to maintain the space held. All participants noted that during this experience they had actually felt like they belonged to a group and they were considering how others might respond. This may explain the adjustments seen and acceptance of falling back to allow continued interaction in the centre, where users’ height was a significant consideration in decision in both starting and retreat positions.

Considerations:

- Presenting a new window, without content, had the same effect as in the previous case, although users knew there was no assigned user to approach. It may have been

expected that a limited or null response would have been seen as in case 1. This suggest a strong sense of immediate learning within this trial.
- The response to the second adaptation in forcing the group back and causing adjustment highlighted the impact of the group being approached and an intra-group awareness towards line-of-sight and preference for viewing location of others.
- The sense of group unity and preservation of cohesion and experience, along with dislike of having the window and interaction reduced, suggests a strong territoriality and ownership of the interaction, while acknowledging the shared nature of the space and requirement for a response.

This study has now considered how a prescribed (or strongly coupled) sense of ownership can mitigate issues of loose formations limiting access to multiple points of interaction for separate groups through social boundary interaction and awareness, and the learned effects of adaptation in supporting a digital awareness of approach.

5.2.3 Considerations

These studies have now considered multiple aspects of display behaviour relative to entry, approach and exploration of presentation and layout changes, further situating previously identified emergent phenomena of social organisations. This has identified elements of the social relationship of users to content windows and the wider meaning this can imply.

The physical impact of presentation and layout have been shown to influence dynamic interactions of users co-orientating around the display, however, a more interesting phenomena is a perceived social-spatial relationship demonstrated in layouts, with a learnt understanding of relationship to windows found through ownership and awareness of social relationships to adaptation. While initial poor presentation and layouts inadvertently lead to reduced usability for multiple points of interaction, users are able to infer the actions of others and requirements of the space through the behaviour of the display, with learned or implicit ownership towards content strengthening this relationship and improving the effectiveness of layout changes. This suggests a wider social-window-display relationship that speaks directly to the user interpretation of the experience.

With ownership seen to greatly improve; local formations, social awareness between content, and response to layout changes, the question arises, how do users identify, achieve and maintain ownership during entry and approach, and what aspects of a system can support this for MISU interactions. While presenting content during entry and approach was seen to offer a sense of ownership, this is not implicit to those at the display until an interaction is achieved and a sense of social relationship is identified. This can be highly challenging for approaching users given poor formations at the display and limited opportunities to identify landing areas or explore an interaction.

With aspects of multiple windows impacting and informing one another, a perceived relationship to window behaviours suggests a powerful social consideration and mechanism in addressing the problem. Where layout changes and adaptation could inform towards potential behaviours of others and simultaneously influence the actions of those engaging at the display, there is a clear need to understand the nature and range of these interactions such that it is handled in a manner that supports all users.

Within this there are two significant limitations to this study; the behaviours and adaptation of the display were not related to the actions or behaviours of users, and the trials were group based leading to more complex phenomena, ultimately limiting identification of MISU interactions, but giving indications of boundary conditions and limitations in the use of layout changes. As the groups were prescribed it could be argued that users were independent of one another, yet the co-location about content windows goes some way to confound this.

The findings of this study indicate a significant range of factors in the overall use of the display, but it is not clear how individual behaviours might differ, as groups (initially) present an inverse response to display factors while adhering to social ones. While the findings indicate that learnt relationships to the display lead to a perceived mapping of display behaviour to expected user response, it is not clear how MISU would engage with a system that actively presents this mapping and attempts to engage users.

Both of these factors now point toward a full scale working system, focussed on the interactions of multiple independent users and an investigation of changing layouts and informed presentation. The clear design recommendations relate to the role of layout and presentation in entry and approach behaviours, what not to do with layout during interaction for a single large group, and the limitations of adaptive layouts in multiple group scenarios, which point to areas for further investigation. These points are expanded upon below.

5.3 Design Recommendations

This now allows interpretations of how aspects of the system should be design based on the impact to social organisation and the role of user experience in interpretation of the interactions and behaviours seen.

5.3.1 Display Factors

- Layout and Presentation of content relate to the position of interaction – The layout will determine the approach location, while presentation will determine the depth from the display. This can be related to multiple groups, however, each on-going group will influence the approach behaviour of the others.
- Ownership can be indicated by changing the layout during entry and approach. This should consider entry position and on-going interactions and formations relative to the display.
- Layouts should not interfere with on-going interactions unless there is a need to inform or encourage a response. Where there is need for a response this should be either indicated or quickly assessable by the user to avoid confusion.
- Presenting multiple points of interaction without considering the presentation and clear labelling of content will lead to removed interactions ("retreat") from the display and reduce the overall effective use of space for those entering.
- Adaptations at the edge of groups can influence the local organisation but also cause users to change their behaviour within the space – there are propagation effects, particularly around awareness which can lead to changing the group interaction.

5.3.2 User Experience

- Adaptation and Layout changes should not cause groups to interfere with an on-going group as this will negatively impact upon both experiences. Adaptation is a permissible form of change as long as it can be readily understood.
- There is a need for a direct social relationship or learned response to a new window for adaptation to have an effect.
- There are personal preference for position and forms of interaction - these may override the effectiveness of adaptation within the wider group experience. Some users may not want to respond, or their initial position does not require a response in the manner that the adaptation implies.
- Adaptations should not impose constraints on group space or position beyond peripheral awareness – groups are willing to move or adjust but should not be made to move multiple times or continually pressured to move where there is not space.
- Adaptation coupled with awareness can encourage feelings of exploration, however, this is linked with ownership and individual preference for engagement. Without clear feedback or external reason the experience is adversely affected.
- Reduced workload is a significant factor in unfolding interactions, either through considerations of the changing layout, understanding the changes via feedback, or in natural social organisation. Understanding and learning can be found through any of these channels, however, the ideal scenario would consider these factors working in unison to support and mitigate the need for the others.

5.4 Summary

Having now considered the nature of group dynamics in response to layout and adaptations, there are significant points of interest which relate to the overall use of space. Presentation and Layout offer strong mechanisms in the approach behaviour, but interact in a manner which requires simplification or wider investigation. Adaptation and localised changes prove to be critical in the overall group experience and can be influenced through a number of factors, including personal preference, localised adaptation and social influences. These prominent points of interaction and experience relative to the overall design, implementation, and engagement with PLID's now leads to a distinct area of investigation.

Where the initial display size resulted in limitations in the factors of design there is a need for a more expansive system to accurately consider MISU interactions, with a fully sensitised system to identify, track and present content to MISU's, along with aspects of adaptation which have previously been considered. With these factors in mind, the development and testing of such a system is presented in the following chapters.

Chapter 6: Study 2 - Responsive system

This chapter presents the development, implementation and testing of the full scale lab-based system, along with the design and development of the first stage of the MISU interaction investigations. This work now represents the first iteration of findings between Phase 2 and Phase 3 described in the Approach and Methodology (Chapter 3), leading to the development of research outcomes and iterative system development for more complex MISU interactions.

The aim of this combined approach is to more fully understand the nature of MISU interactions and the role of changes in display layout with respect to entry and wider on-going usage. This will identify the aspects of layout and presentation which influence individual decision making and behaviour to the social and physical use of space, supported by an understanding of user experience. This will present a set of design recommendations for these types of systems for MISU interactions as a novel contribution to knowledge.

The chapter is broken down in to two distinct sections, with the first outlining the justification and requirements for the lab-based system, with the second considering the design and implementation of the first study. Both sections are derived from the findings of the field work and first laboratory study.

The development and testing of the system will expand upon the display factors in user behaviour identified in the previous chapter. This will consider the implications of a responsive layout and presentation between MISU interactions and the relationship this has to social organisation and phenomena within the wider space during entry and approach. These considerations are characterised by two requirements;

1) Identifying how entry position and the forms of interaction can influence user decision making and social organisation.
2) How do users naturally organise around the display based on the entry position and approach considering social organisations and feedback.

These requirements now lead to the development of the system based on physical relationships of the situated space and theory describing personal space and interaction.

6.1 System design: Justification, Requirements and Development

We will now consider the approach taken in designing and developing the lab-based PLID. This considers how the needs of the display system are derived from limitations in the earlier MISU investigations, and provided a framework for future investigations and development. The specifications for this digital system are then derived from physical constraints of the space and sensing technologies, and paradigms of personal space and interaction modalities.

With display factors identified in the previous study being prescribed this does not give a clear indication of how natural use and organisation emerge. By presenting a "responsive" system during entry and on-going interaction alternative factors of spatial situation and display feedback can be considered in natural use and organisation, leading to identifying factors of display use and adaptation to support and manage MISU interactions.

The considerations for the system design are as follows;

1) The system should support a minimum of seven individual users – this is in-keeping with the earlier investigations as this number offers a rich set of interactions and responses from users and supports the iterative learning from findings.
2) Each users must be able to interact with an individual content window given comfortable personal space and paradigms of content presentation.
3) The display must be situated in a manner which facilitates clear lines of entry from parallel and perpendicular positions relative to the display space.
4) The system must be able to track all users simultaneously without issues of occlusion between users throughout the space and when interacting at the display.
5) The system must be robust enough to identify and maintain tracking, or to handle loss and re-acquisition of individuals.
6) The system must be readily adjustable to account for a range of investigation scenarios on-the-fly to support a range of trials for each group of users.

6.1.1 System Requirements

These considerations now lead to an assessment of the physical space, display and sensing technologies, along with the Grounded Theory describing social and display interaction to derive a set of system specifications. These are as follows;

6.1.1.1 Physical space

The lab-based studies were conducted at the Mixed Reality Laboratory at the University of Nottingham. The space provided a research bay, measuring 6m in width and 4.5m in depth. There were two distinct entry points to the space, with the first being at the front end of the left-hand wall, parallel to the display, the second being in the centre of the front wall perpendicular to the centre of the display. The bay could be isolated with heavy curtains to limit the width of these entry points. These dimensions are in-keeping with those that may be encountered in a public exhibition space.

6.1.1.2 Display technologies

Where the previous study had utilised a large digital display it was not feasible to use multiple versions of the same system, due to physical limitations in proximity and clear borders around the displays which would confound the user interpretation. Instead, several alternatives were considered.

Multiple options were considered to meet the requirements for the display, with; multiple "chained" displays, rear projection, long-throw projection, all having inherent issues given the need for significant height and width of the display, maintaining the dimensions of the physical space, and preventing shadows being cast or introducing bezels, which would cause delineations and prevent a continuous display. To overcome these issue, two ultra-short throw projectors were connected in series and supported from the ceiling approximately 1.5m from the display wall. A high aspect ratio widescreen was cast, with the overall width of the display defined by the position and depth of the projectors. Small adjustments in the translation, rotation, and keystone of the image allowed for tight alignment at the centre line to remove any issue of framing or fragmentation of the final image.

The overhead position of the projectors allowed participants to approach the display to within 0.5m without interference to the image and 0.2m before any interference with content windows. The final projected display was 1.2m deep, at a height of 0.7m from the ground, and a width of 4.8m before brightness and resolution became an issue. Both projectors were connected to a single computer showing a source equivalent image.

6.1.1.3 Sensing technologies

Given the significant dimensions of the space any sensing solution must be able to, either; cover a large portion of, or the entire area, and support multiple senor inputs to account for occlusion or limited range, alternatively, a number of short range high fidelity sensors which can readily be clustered in to an array but produce manageable data throughput. A fuller comparison of these considerations can be found in the Appendix [C1 Sensing Technologies].

Short range sensors, including; Ultra-sonic depth sensors, Near Field Communication, proximity sensors, etc. were all found to provide sufficient fidelity, however, were limited in their ability to be effectively clustered to provide coverage to the entire space and prevent occlusion, or lacked sufficient range to actively cover the entire space when situated on walls or the ceiling. This resulted in longer range solutions being considered.

With time-of-flight and LIDAR systems having issues of fidelity and cost respectively, digital cameras were considered as these solutions present a wide range of functionality for data capture and out-of-band forms of analysis, as described in the literature review. These systems are also highly prevalent in-the-wild and would offer opportunities to apply this approach in-situ. The limitations were the need for optimal lighting conditions for many of these approaches and requirements for greater computing power in implementing an array based system, introducing issues of lighting to the projected display, and prohibitive cost.

Instead the Kinect camera was selected as an off-the-shelf depth and RGB sensor developed by the Microsoft Corporation for the Xbox One and Windows 10 platforms. The system is supported by the Kinect Software Development Kit (SDK) which facilitates easy access to raw and processed data streams and skeleton tracking for up to six individuals. The functional tracking range of the depth camera is shown to be approximately 0.7 - 6m, however, lighting conditions and confounding artefacts can limit this effective range when applying skeleton tracking to around 5m. This either limits the coverage or defines the configuration of cameras to ensure consistent tracking. The sensor has an angular field of view of 57 deg. horizontally and 43 deg. vertically, with a possible pitch adjustment of 27 deg. from horizontal allowing effective identification and tracking. This supports the use of the camera in either high or low elevations to the ground plane without parallax distortion.

The Kinect camera and SDK combination were found to have low system requirements relative to a standard desktop machine, however, the data output is relatively large as all channels are sampled before restricting data rates through software in the SDK. This results in only a single camera being supported on a single computer due to on-board data bus limitations. When this is taken in to account, it is still feasible to reduce the data rate through software approaches to a manageable network and recombination rate at 30Hz for multiple cameras. This would then require a minimum of three cameras to provide total coverage of the space, before requiring additional data output restriction in software. The full report on the Kinect can be found in the Appendix [C2 Kinect Report].

At the time of developing this approach there were no other examples of this technique being applied to create an elastically scalable array of Kinect 2.0 devices, resulting in a novel software based technical solution to the issue of tracking and data capture. The technical specifications of this solution are considered below in the System Development section.

6.1.1.4 Personal space and interaction

With physical and technical realities and restrictions having been considered, the final defining requirement rests in the physical-social needs of users in natural interaction.

In supporting MISU interactions the total width of the display must support all users standing abreast at a comfortable social distance. The Proxemic (Hall, et al., 1968) theory indicates a comfortable personal space of 0.45m radius. This gives a separation of 0.9m between person centres. With seven participants this gives a total required width of 6.3m width, however, considering the context of public space and evidence from Study 1, there are strong indicators that inter-personal distances are less rigorously enforced in certain settings, such as public and exhibition spaces or through familiarity seen in the earlier trials.

If we take the limit of personal space to be side-to-side, describing a display viewing F-Formation (Kendon, A. 2010), we can consider the point separation to be approx. 0.7m or 0.35m radius which describes the width of a single shoulder, adjusting the required width to 4.9m. This seems reasonable to the dimensions of the projected surface (4.8m), with users at either edge of the display not requiring further separation as they are adjacent to walls, offering a relieving effect across the width of the display of 0.7m.

The final consideration of user interactions is the dimensions of presentation and interaction between content windows. In personal computing and content presentation paradigms, adjusting the font size will have a more direct impact upon the viewing position of users than altering the window dimensions. As such, content windows can be reduced in size with a large font still shown without influencing the relative viewing position. This results in the window size being adjustable to accommodate the number and position of users, with the "optimal" viewing position defined through content presentation.

6.1.2 System Development

Development of the final system was a multi-stage process, addressing both physical and technical issues. The physical construction of the display and sensor array was relatively trivial given the dimensions derived from the specifications above. However, technical development was extremely complex and had to consider multiple pit-falls and novel, or at least innovative approaches throughout. The stages of development are detailed below, with the full consideration of design, implementation and code found in the Appendix [C3 Design];

6.1.2.1 Physical System

Considering the specifications derived the simplest approach is to triangulate three cameras around the maximised projected display. This gives a display width of 4.8m, with Kinects (numbered 1-3) positioned on both top corners and a third at a depth of 4.8m from the display to cover the central area. A birds-eye-view of the space and positions of the entrances, display and cameras is shown below (Figure 6-1).

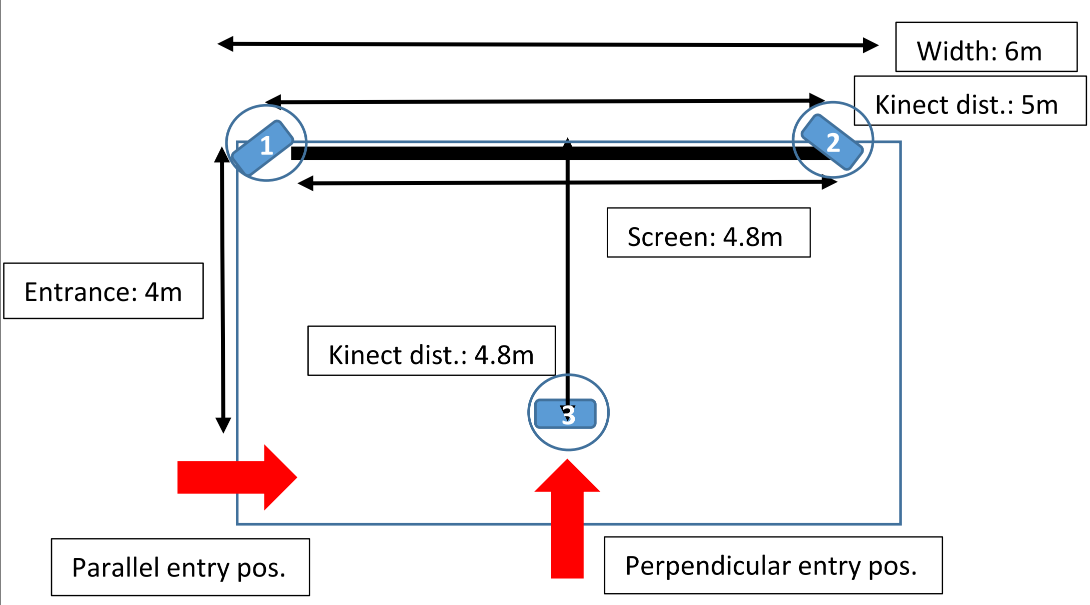


Figure 6-1: Showing the Top view and situation of physical system.

The projected surface was constructed by attaching two 1.22 x 2.44 m (4x8ft) plywood boards horizontally to an aluminium scaffold resulting in a 4.88m surface. The projectors were then mounted at a height of 2.5m and distance of 1.5m from the display and connected to a computer tower behind the screen, with their outputs aligned at the centre line.

Two Kinect v2 cameras were mounted along the top edge at a separation of 5m and angled at 38 deg. to the plane of the screen to maximise coverage of the central area and provide the maximum overlap between the two cameras. This did however introduce two separate areas of limited to no tracking along each wall of the bay, inside of approximately 2.5m distances from the display, which fell outside of the field of view of either camera.

The diagram also shows the Parallel and Perpendicular entry positions relative to the display. The perimeter of the bay space is surrounded with curtains, with 1.5m wide entrances at the two positions. The area behind these positions is open space and is used to group participants without line-of-sight to the display prior to entry. The configuration of the physical system is shown below (Figure 6-2), with the left half of the display shown in the Top (birds-eye view) and mirrored along the centre line, and a Right side projection.

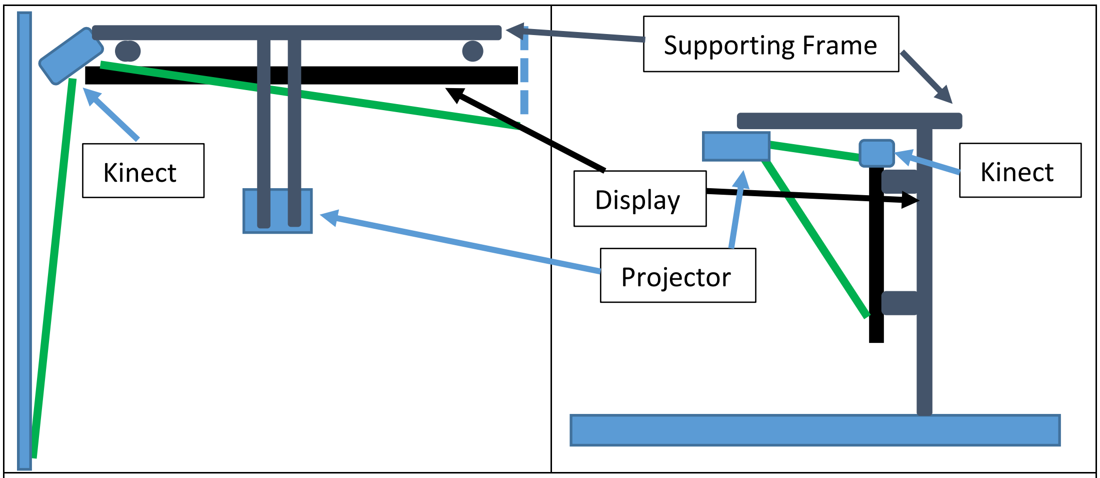


Figure 6-2: showing the Top Left-end and Right Side projections of the physical system.

As mentioned, there was a region of lost tracking along each wall, shown as the vertical blue line in the left hand image (Figure 6-2). The cameras field of view was aligned to the length of the display to maximise tracking resulting in a wedge of un-tracked space, approximately 0.3m wide and 2.5m long. With careful positioning the view was extended to the parallel entrance position to give immediate tracking upon entry, with only the gap indicated not being tracked. During testing it was found that a user would have to stand almost side on to the display for tracking to be lost in these regions, however, lighting and occlusion effects could influence this. Details of the total coverage are given in the technical development.

The final element was the wiring and data handling. In total three computers were used in this arrangement, two were situated behind the display and the third was positioned behind the perpendicular entry point. All computers were connected to the local network with one of the three acting as a server and display output for the projectors. The configuration of cabling is shown below (Figure 6-3);

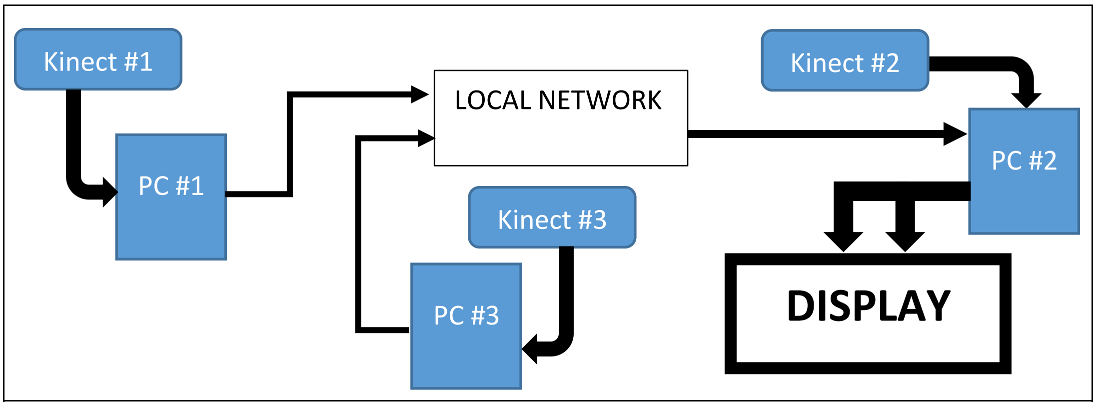


Figure 6-3: Showing the cabling and data flow configuration of the physical system.

The physical configuration of the system was relatively simple given the dimensions found. The complexities and technical challenges of development will now be covered below.

6.1.3 Software Development

The technical development considers the software elements and problem solving in meeting requirements described above. Much of the final system was solved via an iterative process of implementation and testing to achieve the desired functionality. The steps will be outlined where appropriate, otherwise the complete solution will be given for sake of brevity.

6.1.3.1 Initial work with the Kinect and SDK

The first stage of development was to address the data capture through the Kinect v2 and SDK to establish the effective functional range of the camera in the lab scenario and to characterise the tracking behaviour in a number of physical configurations.

It was noted that significant changes in angle at heights above 2m would result in either reducing the effective range, overall viewing area, or tracking capabilities. Flattening the angle above this height resulted in effective range and tracking, however, the near field would be lost to view. The optimal configuration was found to be positioned at 2m with a downward angle of 15deg.. This height ensured that users would be able to pass underneath the camera without obscuring the field of view, however, this shifted the minimum tracking distance to 1.5m as users would not be sufficiently visible to tracking algorithm of the SDK. This was handled via overlap of the fields of view of the three cameras.

6.1.3.2 Client-Server

Multiple computers were required to support all Kinect v2 cameras due to limitations in hardware data rates. As this data rate would present a bottle-neck for a single machine to process all data, streams from each camera were sampled as required, with the additional output from the cameras discarded. This simplification allowed for a single machine to process the data from all three cameras within a single reference frame, with each machine hosting a Kinect designated as a Client and the central machine the Server.

Connection between Clients and Server was achieved through an open socket TCP/IP protocol to allow two-way communication and ensure data packets were delivered in sent order. The local IP address of the Server, along with a unique Client identifier were hard-coded in to the Client software and were automatically registered with the Server when run. Once registered, all configuration and commands would be run from the Server to all Clients simultaneously. Data sampling could then be managed through the Server configuration and issues of data rates handled in software to prevent overflow. A timer was included on the Server to drop failed or “hung” transmissions preventing bottle necking of the TCP/IP socket.

This approach resulted in an elastically expandable array of sensors in any given configuration. Introduction of a new camera required an additional computer running the appropriate Client software and being connected to the local network. The unique Client Identifier (ID) would be used to define how to handle data output through software, with the data recombine in to a single reference frame on the server through known translations and rotations given the cameras physical position and orientation.

6.1.3.3 Recombining the data to reference frame

As each camera-Client has an internal co-ordinate system, cameras could be situated at any position in the space relative to the display. Using the unique Client ID and the known relative positions of the cameras, rotations and translations of the respective data sets could then be handled by the Server to recombine the data in to a single reference frame. The origin of this reference frame (X,Y,Z) was then set to the lower left corner of the display.

An evaluation of the alignment was carried out to assess the accuracies and overlap of the three cameras and to identify the overall tracking area. The output of the tracking was used to further refine the translation and rotation variables assigned to each camera to provide the maximum compliance between the data sources in the centre of the interaction space, as this was the most likely location for users to be. The outcome of this can be seen in Appendix [C4 Camera Alignment]. Any distortions in data due to distance or extreme angle to the camera, meaning the users being around the periphery of the display space, were handled in data recombination and filtering which is discussed later.

6.1.3.4 Transition between Frames - Positive ID – Considering gaps and misalignment

As each camera utilised its own internal reference frame and unique identifiers for tracked users, there was no immediate solution to establish or maintain consistent tracking of users between cameras. An investigation was carried out to establish a persistent tracking ID within the global reference frame at the Server across all data sources. This approach had to account for; transitions between camera view frames, issues of misalignment between frames at extreme range or field of view given the 2.5mm accuracy of reported depth values, and gaps in coverage or overlap between frames resulting in missed or duplicated user data.

The initial approach in achieving an absolute identifier considered biometric modelling via skeleton tracking. Biometrics considers the measuring or metrics- of biological phenomena, this could include retina pattern, finger print, voice recognition, etc. as these are all assumed to be unique to the individual, or to provide a significant level of certainty as an identifier. The initial investigation around skeleton tracking sought to model the relationship between height and dimensions of users' limbs, as these have been shown to carry the widest distribution relative to height. This would lead to a series of ratios between height and limb length, and between various limb lengths, resulting in a unique value for each person no matter the position, rotation or orientation of the camera frame.

Unfortunately there were several issues identified with this approach:

- The skeleton fitting in the Kinect SDK is based on a reverse engineering of body joint position from a mapped silhouette and provides a "best fit" representation of joint position and skeleton dimensions. Where this is fairly accurate in the majority of cases, with average millimetre error, the adjusted camera angle influenced interpretation of body shape within the software, leading to shifting joint positions.
- The high frame rate produced by the cameras had positive and negative influences, with the precision allowing for a median smoothing approach to joint positions to stabilize represented positions. Unfortunately, high rates of erroneous points could quickly overwhelm the filter resulting in a significant error and failed identification.
- With smoothing being ineffective, a small margin of error was included in the calculation of limb length to account for instability in data. Unfortunately, this resulted in the calculation of ratios with a plus or minus margin of error intersecting between persons of similar height and build.

While this approach did not end up being used the underlying mechanism proved extremely interesting, and if combined with a secondary data analysis approach, such as Histogram of Orientated Gradients video processing to also consider skin, hair and clothing colour, this could add a significant tool to the elastic Kinect array.

As a unique identifier could not readily be found through the skeleton data, a secondary approach was considered through the application of modelling and simulation literature. The Newtonian and Cellular Automata models both consider the actions and interaction of single points in space where this point has its own inherent variables related to its behaviour, such as position and velocity. By constructing a point in space which maintained its own attributes and variables, the output of each frame could be compared to the list of known points and User ID's along with their internal values to determine the ID to assign to the incoming data packet, this could then be handled by the system.

As discussed above with biometric tracking there were issues with the consistency of the data capture and handling of points in space, however, median filtering and margin of error were again employed in this process. Due to the simplified model of position, the error could be significantly reduced with the majority of the noise being handled by the median filtering and averaging multiple central body joint positions, instead of single point comparisons which were used in the biometric approach. The result was a robust identifier that was able to account for small discrepancies in camera alignment and occlusion between users.

There were several issues that were later identified in the approach; gaps in coverage could mainly be handled unless the distance was significant or there was a marked change in the users' behaviour while not being actively tracked. A further error was found in the persistent identifiers being reassigned to users if it was dropped in a gap or at the edge of the tracking area and another user subsequently passing through that location.

The first of these issues was resolved by adjusting the margin for error in real time as tracking became uncertain. This included extending the direction of motion when in a gap, but also increasing the diameter of re-acquisition with each frame to account for changing direction. This had to be carefully considered to ensure that the diameter did not expand too far, capturing other users and being incorrectly assigned, with perhaps a conical, or field-of-view projection being more applicable. The solution was to reassign the identifier as a new ID, so moving it to the bottom of the stack. This allow for the ID to be maintained, in-case the original user was currently in a gap, but would prevent the ID being assigned to another user as they would have been correctly assigned when passing their own ID further up the stack.

The second issue was more difficult to identify as camera edge effects were not clearly related to any particular set of behaviours or error, but instead were a caveat of tracking limitations and user behaviour. The main issue was found to be user congregating at the rear of the space before all new users had entered, this could lead to failed tracking or identified "stationary" behaviour within the unique ID. At this stage any new user passing through the boundary of the tracking area could be assigned that ID. While the ideal solution would have been the introduction of additional sensor to provide significant tracking redundancy, this was not feasible at the time, instead each inactive ID after being moved in the stack was assigned a timeout function and was removed. Unfortunately this meant issues of lost user data and re-assignment to on-going users, but it was a necessary step to maintain system stability and fortunately was not a highly common occurrence.

6.1.3.5 Data Handling

Having considered the process of acquiring the data, the next stage was to handle and process each data source and recombine the information.

Again this was non-trivial, given the data capture rate of each camera was inconsistent, given dropped frames and buffering, resulting in fluctuation between 25-30Hz of any given device. This was further exacerbated by network latency and socket protocols introducing a further inconsistency in data transfer. Finally, when considering system based analysis and display output it is critical that operations are handled in a time dependant manner to prevent rapid rate changes or shearing in the displayed image, as this will have a significant impact upon user experience and may confound reporting of the interaction by users.

The solution was to separate out the operations and handle them as independent entities, while simultaneously considering the timing and data transfer problems between them. This means the system is now a multi-threaded asynchronous problem.

The main consideration for the function of the system is to produce consistent display output relative to the inconsistent data capture rates. The minimum requirement for smooth digital animation is a refresh rate of 25Hz, as this is the upper range of human vision processing, however, the higher this rate the smoother the dynamic changes will appear. A rate of 50Hz was selected for the display output to ensure smooth transitions of the image, but also for reasons of animation of content windows which will be considered later.

As the display output is fixed this gives a known sampling rate of the internal database and when it can be altered. As such, all write and processing operations must be held within a set of confines to prevent multiple read/write operations occurring simultaneously, leading to incorrect data values or a system crash. This was handled with a three stage process:

1) Data read/write operations were held within a Mutex, which locks the database to only allow a single calling point at any time. If this Mutex was denied a lock as it was in use the call would hang until the lock was released or new data was transferred. This ensures the most up to date values were processed first.
2) Data processing required the most concurrent data. While the Mutex would prevent data being written during processing, the need for consistent data to the display meant that the newest data must be available to the Display Handler at all times. As a result, the processed data output would be immediately copied to a Display Handler buffer as the Mutex was released.
3) The Display Handler which collects and processes the display output had an internal increment, which if refused access to the database due to a Mutex lock, would display the previous frame with interpolation of the same animation values from the buffer, maintaining a seamless transition of dynamic content and not simply showing the image a second time leading to stuttering.

Combining these three considerations it was then possible to construct a stable system to handle all three operations of; data input, data management, data output. The data flow through the software is shown now below (Figure 6-4):

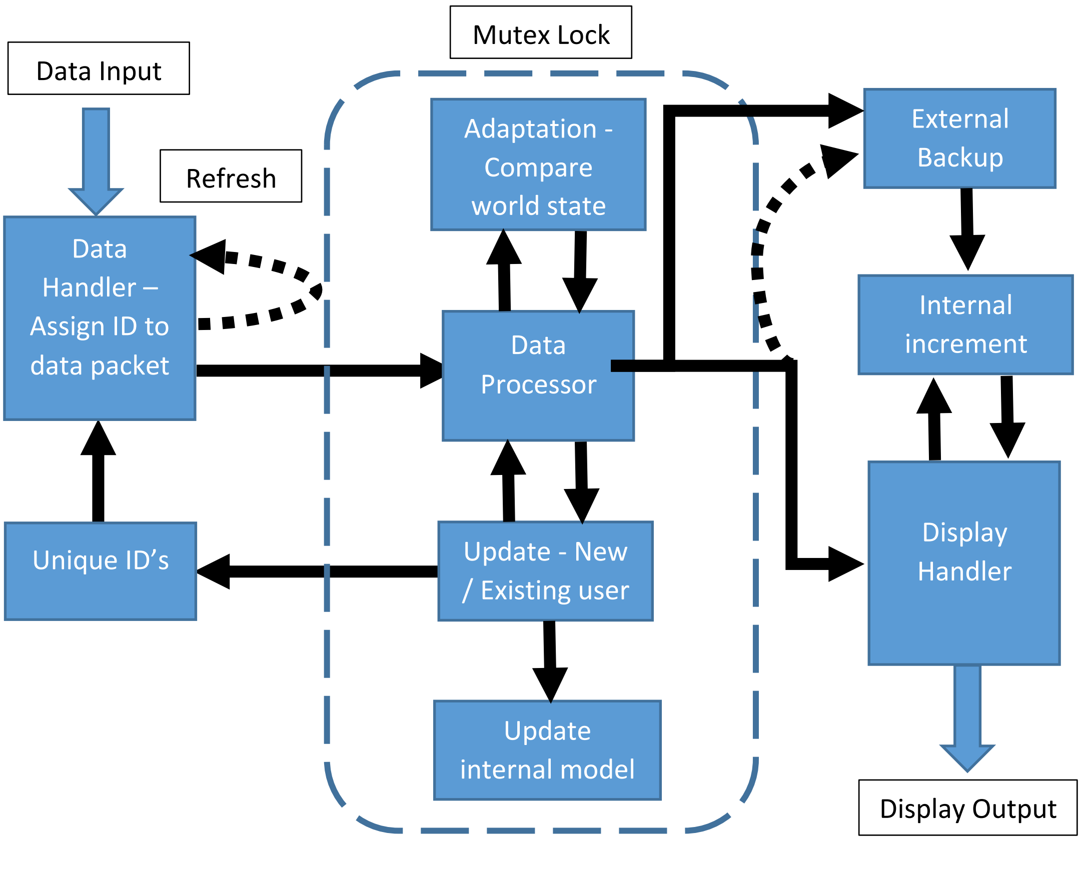


Figure 6-4: Showing the data flow approach of the system and main software modules involved in handling and processing the data flow.

This model present an extremely simplified version of the overall software solution, however, the resulting approach provides robust and reliable data transfer, processing and display options. This software design allows for any aspect of the programme to be altered to account for hardware or processing limitations without affecting the operational performance and simultaneously maintains a consistent user experience.

Points of interest within the diagram are:

- Display Handler module. This relates all factors of content windows to be displayed to construct each frame being shown. This handles all interactions between windows and the final presentation of content based on the output of the data processing. This is described in greater detail below.
- Adaptation module within the data processing Mutex. This module contains the configuration for the adaptation mappings which are applied throughout the studies. This considers the global configuration of the system i.e. the study design, and world state of all tracked users relative to the display. This is critical when considering forms of content mapping and display adaptation and when to apply them. This will be detailed in each study chapter as each tests a different set of interactions.
- User internal model within the data processing Mutex. This considers the positon, velocity, proximity and form of interaction state for each users individually and is used to derive the modelling of behaviour relative to the display and world state. This is considered in the final study chapter (Study 4 - Prediction).

Having considered the approach towards handling and processing data, the final stage was to address the mechanisms of display output to provide a streamlined users experience, but also to facilitate testing of layout and presentation factors.

6.1.3.6 Display output

The display output is ultimately controlled by the Display Handler (DH) module, which is responsible for configuring and managing all aspects of the projected display. The DH handles the configuration of the display dimensions and offset of the screen relative to the origin, as well as feedback, content, and dimensions of the content windows.

As described, the output is set at a fixed rate of 50Hz and utilises a data buffer combined with an internal increment to support consistent frame rate. This is achieved via a fixed timer loop which calls the data pull request and screen draw function. To ensure the display rate is met, the pull request for concurrent data, or increment of the data buffer are called between frames and rendered to an internal buffer. As the draw function is called this buffer is immediately shown and the process is repeated. This follows an established paradigm for graphics rendering and presents the most consistent method of smooth graphics output.

Data output of the data processor considers the position and "state" of each user as individual objects which are bundled and passed to the DH. The DH is then responsible for interpreting the relationships between each user via the trial configuration. This is derived from the unique user ID and a parent-child relationship to each content window. At the buffer stage the DH calls each content window based on depth of the user to the display and updates the internal values of the windows position and state. The content window - child object of the display, then applies its own internal logic to determine how it should be displayed based on the trial and mapping. When all windows have been updated the DH loops through all windows and draws them according to their internal presentation variables.

Again, this approach is taken from established video game design approaches as this presents the maximum level of flexibility in presentation and layout handling with a minimum level of complex high level management. This approach allows for specific relationships of the content window to each individual user, for factors such as; height, distance from the display, interactions between users and consistency in content presentation. This is a highly critical factor in the design and implementation of the display interaction studies. The specific nature of the interactions between windows and the internal state of the content windows is more fully described in each trial relative to the study design.

At the time of developing this solution, there were no examples found in literature describing the problem or solution as put forward. As with several steps in the development process, this body of work produced a robust, novel and innovative solution to a previously unknown problem and presents an area of interest and future work going forwards.

Implementation was ultimately a two year iterative process, combining multiple aspects of development, testing and validation of complex problems to achieve the functionality and a robust yet adaptable system. Several of the solutions presented may be considered as contributions to knowledge, with the system itself being a unique interpretation of technologies and software in delivering a novel test platform. With all things considered, development of the first iteration of the investigations of MISU interaction is now presented.

6.2 Study Design and Implementation

This section now considers the design and implementation of the first study of MISU interactions with the full scale lab-based investigation. The study considers the nature of entry positon and presentation factors of multiple points of interaction during MISU interactions, to determine the role of user awareness and display feedback during approach in the formation of emergent organisations and on-going engagement behaviour.

The study will simplify the previous approach by removing confounding issues identified in group scenarios to focus on multiple individual users engaging with discrete points of interaction. The ideal scenario would see each user achieving an individual window for maximum display utility, through an awareness of on-going formations and display feedback during entry and approach. This will be done in a between and within comparison of entry position and forms of feedback in window interactions to establish the nature of user behaviour compared with the current understanding of display changes.

The previous study has indicated the significance of awareness of layout and presentation in decisions making during entry and approach. This study will test how mapping these factors to real time interaction behaviour of MISU's can inform our knowledge and understanding of these phenomena. By using system functionality to map content directly to the user's position and allowing resolution of local window interactions through feedback to better understand the impact upon emergent phenomena and organisation around the display.

Known as the "Responsive" system, window layout has a one-to-one mapping to user positions i.e. X user == X window (exactly equals). This builds upon the idea of social-display relationship identified in the previous study by immediately introducing the relationship and feedback effects which were associated with ownership and window movement. Instead of the prescribed window colour relationship, ownership is presented by mirroring user movement from the point of entry. Where users came into close contact, changes in window presentation would be determined by the local Proxemic relationship defined in literature.

As the display space becomes fully populated i.e. seven participants at the display, emergent ecologies of phenomena will lead to natural formations of interaction, with aspects of display behaviour being evident through changes in observed behaviours.

The study considers two critical factors of user position and display response;

1) Entry position relative to the display – Parallel and Perpendicular to the display.
2) Content Window interactions relative to depth of respective users – Hiding or blurring windows when overlapping.

The entry positions, shown in the "Top View" of the physical system (Figure 6-1), are both 1.5m wide and have a staging space behind the curtain wall of the bay. These spaces act as waiting areas for participants, with no line-of-sight to the display to prevent confounding or learning effects between participants' entry. This considers the awareness and learning of users when entering the space and approaching the display from varying positions during degrees of use, establishing the role of on-going use and display feedback in altering local formations, and in turn the impact this has to previously identified phenomena.

Content window interactions consider two distinct states of display behaviour; Hidden and Blurred windows. This describes the interaction between content windows during overlap, which occurs when two users pass one-another at a horizontal position at the display. This factor investigates the reported sense of ownership and "connection" to individual content windows by users, and how the relationship to the display changes as users pass through peripheral on-going interaction space. These interactions are shown below (Figure 6-5);

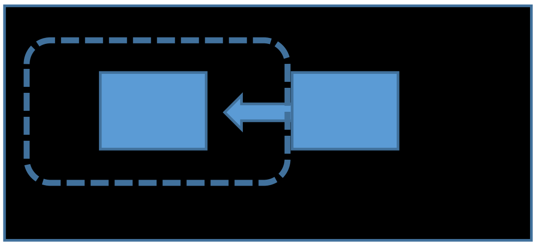
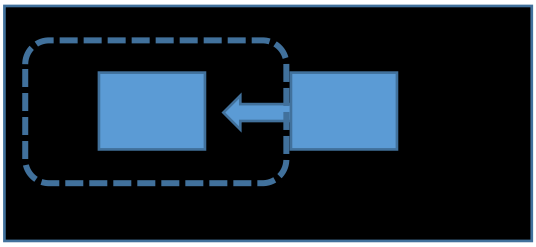
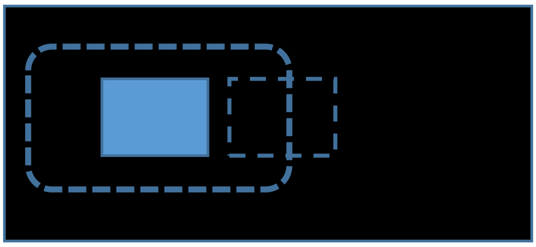
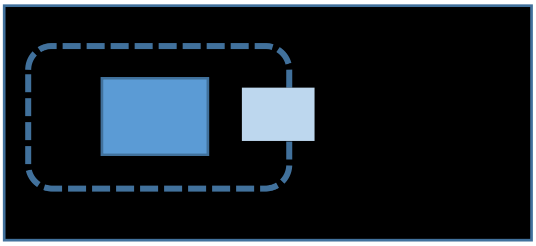
HIDDEN	BLURRED
	
	
As the user passes behind (from the right) and enters the peripheral vision (area) of the user closer to the display, their content window is hidden from view while their position falls within the boundary area.	As the user passes behind (from the right) and enters the peripheral vision (area) of the user closer to the display, their content window is reduced in size and opacity, giving the impression of moving behind.

Figure 6-5: Showing window interaction behaviours during overlap.

In both examples the mapping of the content window to user position is maintained as part of the Responsive System design, with changes in presentation indicating a form of feedback. The layout and presentation of windows is managed based on the defined boundaries of view area i.e. 0.35m to the left and right of each user (1/7th of the display width). This leads to considerations of how users perceive and maintain a sense of ownership and "connection" to their window and the display throughout their approach and on-going awareness.

As the blurred window shrinks in the peripheral area of the on-going window, it is completely obscured when passing the boundary of the window itself. This explores the relationship of the mapping and ownership to the user moving behind, but also further considers the natural channels of formation and organisation between MISU's when interacting at the display.

A between and within study design of these factors accounts for confounding issues, and explored learning effects of users towards the perceived interaction. This results in four distinct trials between two designs (Table 6-1).

	Trial 1	Trial 2	Trial 3	Trial 4
Design 1	Parallel - Hidden	Perpendicular - Hidden	Parallel – Blurred	Perpendicular – Blurred
Design 2	Perpendicular – Hidden	Parallel - Hidden	Perpendicular – Blurred	Parallel – Blurred

Table 6-1: Showing the counter-balanced order of trials run within the study 2 design.

The entry condition was tested between trials, with the window interaction as the within variable, given that the nature of the entry position would determine how and where participants would gain awareness of the display and begin to form their engagement with the on-going configuration. This would allow for clear observations in the entry awareness and behaviour and then subsequent understanding, learning, and interactions between users both with and without the window interactions influencing the emergent behaviours.

These behaviours were considered in a two-fold approach:

1) What are the observed interaction behaviours in relation to both conditions and how do these relate to the established literature, observations and previous studies.
2) What is the user experience in relation to these factors and interactions with other users throughout the experience.

The study considered four repetitions of each design with 7 participants in each iteration. Participants were asked to form a line in the staging area before each trial, mixing their order each time such that each participant would experience entry position between 1-3, 3-5 and 5-7 at least once throughout the study. These distributions of participants were considered in the post-trial interviews and analysis. Participants were then asked to enter the space at five second intervals to ensure sufficient time to observe the display but not potentially complete their approach, giving time for observation and learning effects during entry. Participants were asked to find a content window and read the text that was shown, but were given no additional information about the interaction. Each window presented a randomized article of text which would require several minutes to read allowing all participants to enter.

Video data and researcher observations were carried out throughout entry and interaction, with there being no limit to the amount of time this could last. Notes would be taken during these observations to serve as key points during semi-structured interviews after each trial. Interviews would consider the immediate response of the group via open ended questioning, with opportunities for all participants to share in their experiences. After the initial feedback, specific points of interest would be addressed, again with opportunity for all participants to comment at any time. Finally, a short series of experiential questions would be proposed to assess the understanding and wider implications of the system function to the participants.

After all trials had been completed the participants would be asked to complete a final round of semi-structured interview, with a more focussed assessment of the experience and overall meaning of the system behaviour. This would ask all participants to consider what had been seen, what it may have meant, and how the system could behave differently in achieving a range of tasks related to the interaction they had just seen.

The final analysis of this data was carried out via a thematic clustering approach with comparison to codified video data of the interactions. The themes in both the video and transcriptions of interviews were compared to attempt to identify the root causes and relationships between behaviours and establish an understanding of decision making relative to social organisation, phenomena of interaction, and display behaviour. There was particular emphasis on behaviours and phenomena which had previously been identified in either the supporting literature or in prior studies.

6.3 Findings

This section presents the findings and considerations of this study. Given the volume of data the findings are presented as thematic representations and key points. These will describe the evolving nature of the interactions and influences of the system in user behaviour. The findings of the study are shown in the Appendix [D1 Transcripts].

The following sections will consider;

- Entry Behaviour and the initial interactions with the system
- Critical aspects of display and user interaction behaviour
- The evolving nature of interactions with system Feedback
- Key factors of display feedback and user experience
- Considerations of system use and user behaviour

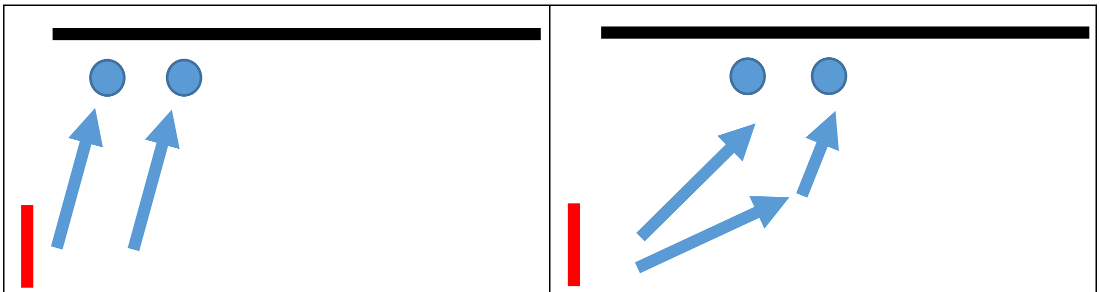
6.3.1 Entry Behaviour and initial interactions with the system

This section presents the key themes in the initial interaction in the two entry conditions and the influences of learned behaviour and interactions between them. This assessed how entry position and awareness of display lead to emergent social phenomena and influenced overall usability.

Both entry conditions were tested in a counter balanced study design, with the range of responses for both conditions described below;

6.3.1.1 Parallel

The parallel condition saw users entering from the left side of the display space at a distance of approximately 3.5m from the display. This now shows the range of interaction behaviours of users engaging with the system for the first time. The first two users were seen to exhibit two general behaviours during entry and approach (Figure 6-6):



Behaviour 1: The users would notice the responsive mapping and immediately approach the display at the left most end.	Behaviour 2: The users would notice the responsive mapping and proceed in to the space investigating the movement.

Figure 6-6: Showing the two general Behaviours of the first two users entering from the parallel position with the responsive mapping.

As users were staggered by several seconds in their entry, the previous users would either be at the display or essentially stationary by the time of entry of the next. The position of users at the display was enforced by the font size requiring users to approach in order to read. This limited the awareness of the mapping between users during entry meaning approach was relative to the on-going use and individual learning.

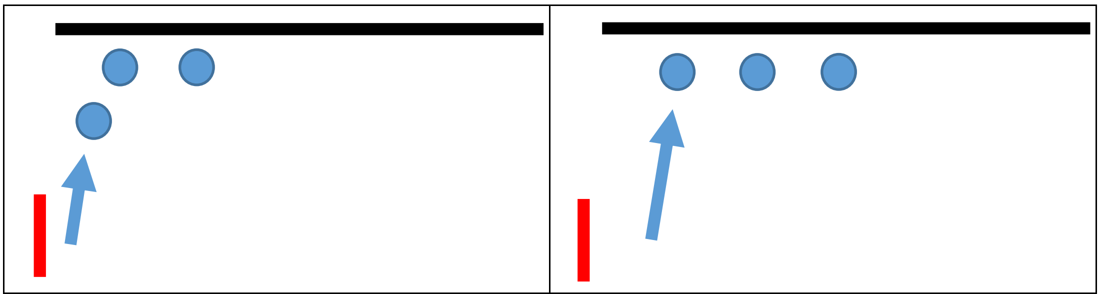
These two Behaviours indicated two different investigation approaches by users:

Behaviour 1: Users initially identify the window and are quick to engage with the content. Once at the display there may be investigation of the responsive mapping.

Behaviour 2: User are more engaged with the responsive element and choose to investigate this factors as part of their approach.

With both behaviours, later users approached the on-going users as there is little to no indication of interactivity or available content. The key difference was seen in Behaviour 2, where there was a portion of the landing area available, with on-going users more central to the display causing a leading effect. This resulted in three critical behaviours of the next user:

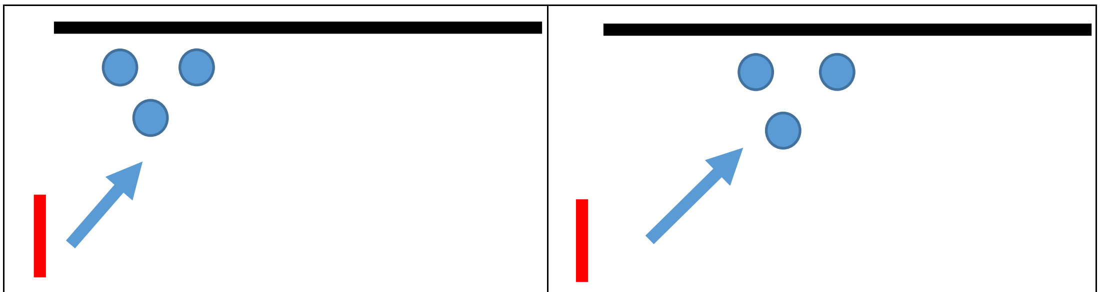
- The next users would approach to the left hand side of current use (Figure 6-7).



Behaviour 1.1: New user approaches the left end and stands behind the group shoulder surfing.	Behaviour 2.1: The user would identify a new window and the interactivity and so approach the landing zone.

Figure 6-7: Showing the first entry behaviour of the third user entering from the parallel position with the responsive mapping and hidden window interaction.

- The next user would approach the rear of current use (Figure 6-8).



Behaviour 1.2: New user approaches the centre and stands at the rear of the group attempting to read the content over shoulders.	Behaviour2.2: The user would approach the group directly with little consideration of the display. The presence of content was a large enough draw.

Figure 6-8: Showing the second entry behaviour of the third user entering from the parallel position with the responsive mapping and hidden window interaction.

- The next user would approach the far side of current use (Figure 6-9)

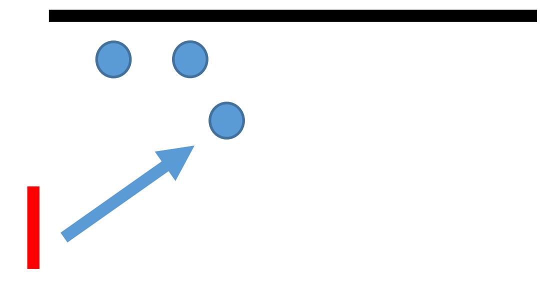
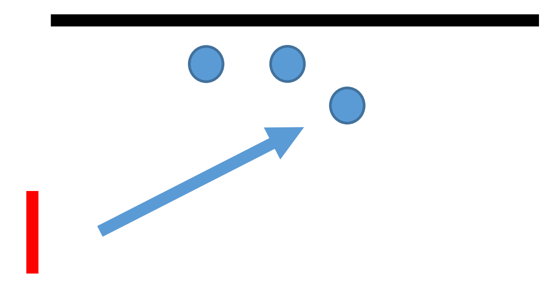
	
Behaviour 1.3: New user approaches the right end and either attempts to read the content over shoulders or identifies the interactivity of the display.	Behaviour 2.3: The user approaches the group and passes behind while assessing the content, before either shoulder surfing, or identifying the interactivity.

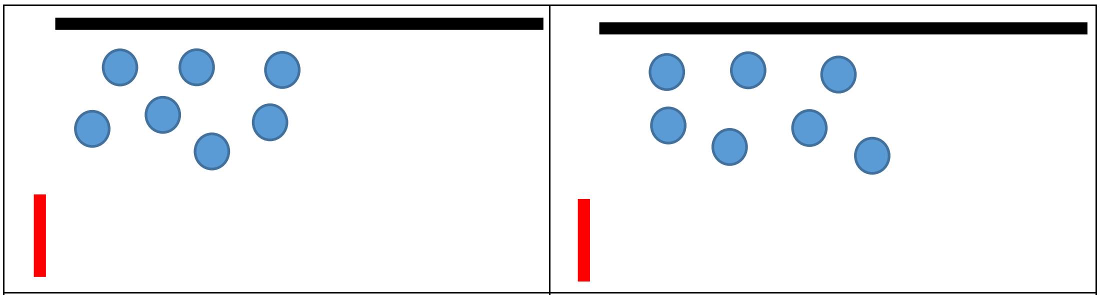
Figure 6-9: Showing the third entry behaviour of the third user entering from the parallel position with the responsive mapping and hidden window interaction.

The observed Clustering behaviour of the new users entering the space follows on closely from the Honey-Pot Effect and was seen on multiple occasions. Once the user has entered into the rear of the group there is little chance they will identify the interactivity and this also increases the cluster size, so increasing the effect.

As additional users entered the space these behaviours may be repeated or come into effect in any given order, with Behaviours 2.1, 1.3 and 2.3 (edge effects) having a distinct impact to the outcome. Behaviour 2.3 would only take place once, but was not restricted to the third users, and was instead related to the individual and their awareness vs. the draw of the cluster and content shown. Many early users did not notice this and were drawn to the group instead (1.2 and 2.2), indicating the Honey Pot Effect of the cluster can be extremely strong.

With Behaviours 1.3 and 2.3, users would approach and shoulder surf to allow viewing, inadvertently offering the potential to discover a new window, however, this was not common due to the “hidden” nature of windows requiring a separation of at least 0.7m, where the tendency was to form rows and read over the shoulders of those in front.

As successive users entered the space, the above examples were repeated in a variety of orders, such that users would either engage with the cluster or the display in the manners described above. As density increased Behaviour 1.3, if not seen during earlier entry, would become forced as users adjusted around the limited space in front of the content windows. The higher earlier distribution in Behaviour 2 would always see Behaviour 2.1, but the distribution made 2.3 less likely as the cluster finally formed. The final outcome of these engagements would see a final cluster of users with limited distribution across the display, instead forming rows, these are now shown below (Figure 6-10);



The users form a tightknit cluster with several rows and up to three individual windows which were all shared.	The users form a more disperse cluster with several extreme outliers and up to three individual windows.

Figure 6-10: Showing the general organisation of users after entry from the parallel position with the responsive mapping and hidden window interaction.

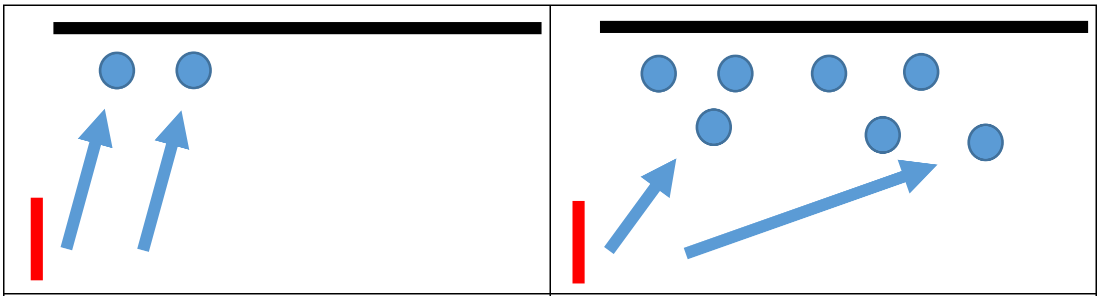
The result of shoulder surfing and clustering was to "lock in" on-going users to the configuration. Where they had initially enjoyed exploring the "Hidden" interaction, this was quickly limited by a lack of space and a need to maintain "ownership" and position to ensure stability of the window as the "Hidden" interaction was not fully understood. With increased clustering "locking" the window positions there was little further exploration from later users, and so the clustering effect was bolstered and the final distribution was extremely narrow compared to the width of the display.

There was a single example of users passing the centre line of the display leading to a fourth window. Seen in Behaviour 2.3 where the user "spilled over" from their initial approach and established a new window. The predominant factors of Behaviour 2.3 was a "barrier" effect, where users would stand back and to the right of the group, but not identify a new window. Once orientated to the content from this position they would act to limit any further movement past that point, and so "capture" later entry, forcing user to join the cluster.

As part of the experimental design, the entry condition was run in a counter balanced approach, with the window interaction behaviour kept the same. This assessed critical changes in entry behaviour between the conditions due to either learning or user expectations. With the second interaction with the system users were asked to mix their entry order so that the first three users from the previous trial would not enter within the first three positions.

The entry condition was run in the same manner and showed three distinct patterns of entry and interaction behaviour from users who had previously entered in the perpendicular case:

- Immediate approach to the left hand end of the display (Figure 6-11)



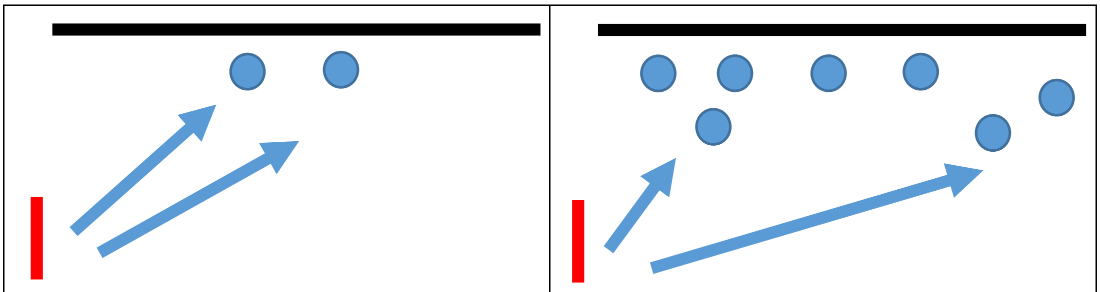
The initial users would engage with the interactivity of the landing area and would immediately approach the display.	Subsequent users would investigate the open areas of the display but would still show localised clustering.

Figure 6-11: Showing distribution and local clustering of user when entering from the parallel position with hidden window interaction after seeing the perpendicular case.

The initial users would have little experience of the interactive system and would immediately investigate the responsive mapping, similar to Behaviour 1 seen in initial entry in this condition. Later users who were more likely to be aware of the mapping would distribute through the space, with the further positions from entry being less evenly distributed and many users not approaching the display directly. Within the later entries there may be users who are unfamiliar with the nature of the system and so join those at the display in a similar manner to their previous experience.

With those who had a window at the display there were large gaps left between windows, but not sufficient to readily allow a new stable window, with the "hidden" window interaction causing "flashing" between windows. This was due to windows interacting at the 0.7m boundary of the interaction condition and was reported to be very annoying. The size of the separations and lack of clear feedback prevented additional windows being created by new users and created local clustering behaviour around the windows which were shown.

- Approaching the centre of the display (Figure 6-12)



The initial users would engage with the interactivity of the landing area and would move through the space to investigate.	Subsequent users would either approach the landing area or the open space at the other end of the display to find a window.

Figure 6-12: Showing distribution and interaction with a landing area of users when entering from the parallel position with hidden window interaction after seeing the perpendicular case.

The initial users would identify the interactivity and continue moving through the space to investigate the mapping, similar to Behaviour 2. As additional users entered the space there was sufficient landing space for investigation. In several cases there were individual users who would immediately approach the gap on the right hand end of the display without considering the landing area or on-going interactions. These users were likely familiar with the nature of the system and were able to make a decision based on the available space.

As the landing space on the left was available this allowed for greater investigation and creation of new windows. The same was seen in the gap on the right. This ultimately led to large numbers of windows being created, however, the issue of the window interaction still resulted in large gaps between windows, or significant flickering and adjustment from those at the display until this was resolved. Again this was reported to be annoying.

This trial resulted in a greater distribution across the display and opportunities for several users to investigate the display and receive windows. While there were several issues of loose distribution due to window interaction and localised clustering, most users were able to observe or engage with the display in a more refined manner than in the first interaction.

- Distributing across the display (Figure 6-13)

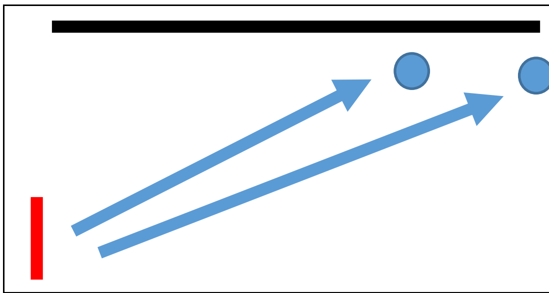
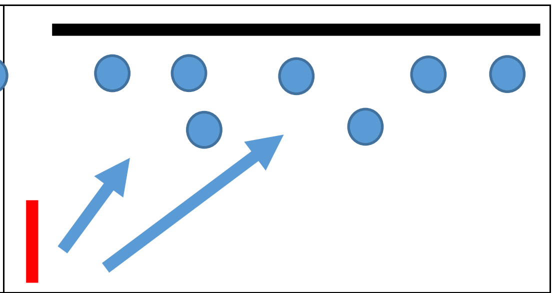
	
The initial users would engage with the interactivity but move almost completely to the far end of the display.	Subsequent users would approach the landing area and either interact directly or move into the space.

Figure 6-13: Showing initial distribution leading to greater exploration and distribution of users when entering from the parallel position with hidden window interaction after seeing the perpendicular case.

The initial users would engage with the display and window mapping, but appeared to make a conscious effort to move directly to the far end of the display. This seemed to be a combined factor of investigation, awareness of the system function, and awareness of additional users due to enter the space. It was interesting to note that the second users to enter approximately followed the initial entry as a form of leading effect.

Following users exhibited a combination of immediate interaction, landing, and relaxed exploration during approach. As distribution increased the final users were seen to form local clusters, where there were still gaps present at the display. Little effort was made to interact with the system as users assumed a maximum number of windows were being shown.

This approach proved effective in distributing users, although there were issues of clustering due to assumptions about the nature of the system from the previous trial. The early decision of users to move to the extreme end of the display introduced a leading effect resulting in a greater distribution. Later users would also approach larger gaps to allow for better line of sight without having to impact upon the on-going user in a significant manner.

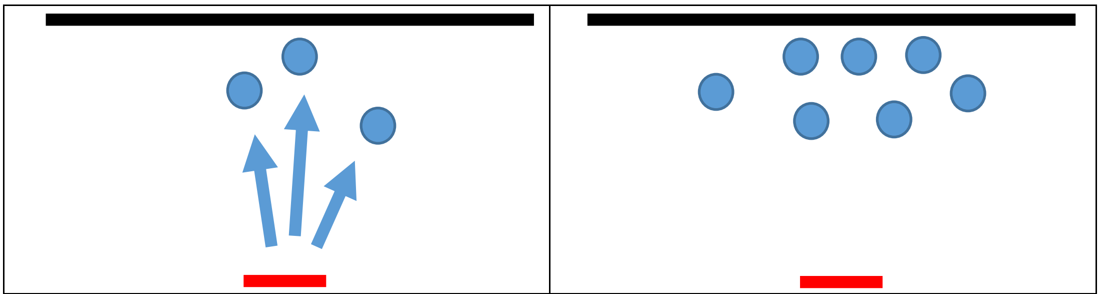
This suggests that prior experience and awareness from the perpendicular entry supported wider investigation and use of the display compared to the first interaction in parallel entry. Less experienced users showed repeated Behaviours, however, actions by more experienced users led to greater distribution and higher levels of usability. Prior experience of the window interaction was a major limiting factor in engagement for multiple users as this was seen as an extremely negative factor in user experience and was avoided where possible.

While this trial proved more effective than either of the earlier Behaviours identified in the first experience of this condition, the final effective use of the display was lacking, with many factors of localised clustering still evident and a limited overall use of the display. The combination of inexperienced users automatically adopting clustering behaviour, coupled with uncertainty of the window interaction led to ineffective distribution of windows and issues of intrusions and flashing. With no clear mechanism to generate additional windows the final layout was still somewhat lacking, although the majority of the display was used.

6.3.1.2 Perpendicular

The first entry with the perpendicular condition saw users entering along the centre line of the display from a distance of around 5m. Users were not able to see the display or the approach of those before them and would experience different levels of approach behaviour based on the previous users speed. This now shows the interactions of users engaging with the system for the first time while in the perpendicular condition (Figure 6-14).

Throughout this configuration there were very limited number of interactions, with each trial exhibited very similar behaviours.



Initial users would approach the display directly and spread slightly as new users entered.	Final users would approach the rear of the cluster and shoulder surf.

Figure 6-14: Showing the general organisation of users in the perpendicular entry condition with the responsive mapping and hidden window interaction.

This saw the first user approach the display with the following two approaching behind and to the side, allowing one or both to discover new windows. In several cases the initial user would be investigating the mapping of the window which would indicate this behaviour to the following users. The depth of the entrance position from the display allowing for sufficient lateral movement to explore the interaction and form a new content window.

Later users would then approach the cluster from the rear, with those at the extreme edge positions potentially identifying the interactivity. Occasionally the second or third users would adopt a wide positions at the display, leaving gaps for new windows to form, however, this gap would need to be sufficiently large to allow a new stable window.

This case proved more effective than the parallel condition in allowing multiple users to have an individual window, with four windows being achieved in most cases and five in a single case. The earlier users to approach were able to observe the behaviours of those already at the display, but also had sufficient landing space to move in front of the display to discover the interaction. This resulted in several windows forming very quickly and users exploring the interaction and distributing themselves across the display, through a combination of two edge effects (Behaviour 1.3 and 2.3) and lower pressure on immediate space.

Where the cluster formed it would usually be the first users' who had windows that would be grouped centrally, except for in a single example. The distribution of the cluster allowed four windows to be shown, however, this would lead to clustering of later users as landing spaces were limited, mitigating investigation of the mapping and window interaction, with cluster density less pronounced and users appearing more relaxed and explorative.

An interesting factors was highlighted with a single user identifying the interactivity and moving to an extreme end position as part of exploration, reported as a personal preference.

> "… I realised the window was following me … I had space and I could move, … I felt like I wanted to be in the corner out of the way because I knew there were more people coming up behind me, and I didn't want to be in the way … I don't like to be crowded"

This highlighted several aspects of individual nature and the influence of the system in behaviour. The wide location this users selected allowed for an additional window to be created between their location and the centre of the display leading to five windows in total. This was only seen in a single interaction, but indicated aspects of the configuration and personal preference. These factors are considered in greater detail in a later section.

The second interaction with the system in the perpendicular condition proved to be extremely interesting when compared with the changes in behaviour seen in the parallel case. As the users had previously been seen to form relatively tightknit clusters upon entry, the behaviours in this condition proved extremely similar to the first perpendicular entry condition. Shown below (Figure 6-15).

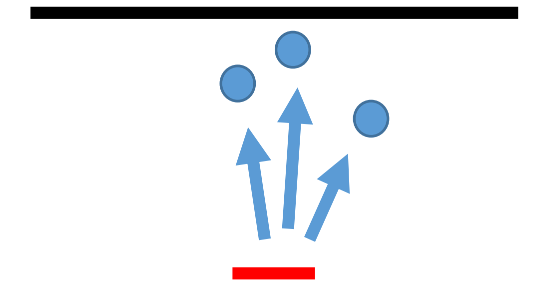
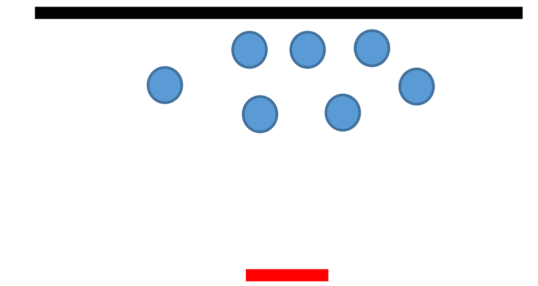
	
Initial users would approach the display directly and spread slightly.	Final users would approach the rear of the cluster and shoulder surf.

Figure 6-15: Showing loose clustering of user's entry in the perpendicular condition with hidden window interaction after entering in the parallel case.

Several of the early entries would begin to approach the first window in the early stages of forming a cluster, as had been the case in the parallel condition, however, edge effects and exploration were seen and there were several windows formed relatively quickly.

With subsequent entry there was exploration from those who had experience of the interaction, with users actively approaching the edges of the cluster and discovering new windows, while users with limited experience were seen to approach on-going windows and form clusters. This lead to approximately the same configuration seen in the initial interaction with this entry condition, with the exhibited behaviour being extremely uniform over all groups.

This suggests that the expectation of limited interaction and a requirement for clustering from novice users, seen in the prior experience of the parallel condition, limited the investigation of the display to a basic level of understanding, resulting in the same distribution seen in the first use of the perpendicular case. As users had no additional information about the system it was as if they were using it for the first time.

6.3.2 Critical aspects of display and user interaction behaviour

Considering differences between entry conditions there were several user behaviours and display factors reported. These relate more closely with user experience and understanding of the interaction. These were;

Ownership: Where users were able to interact with the mapping directly there was a strong connection or "ownership" over that window stemming from moving in sync with their position, reinforcing the window appearing during entry. This received an extremely positive response and was a major influencing factor in early approach to the display, especially in parallel entry where lateral movement was pronounced due to the entry condition. Later users did not report any sense of ownership and in many cases were not able to identify the mapping.

Early users suggested that all users should be able to experience the window interaction as it was a clear indicator of ownership and that it would likely prevent attempts to share windows, which was seen as negative. It was also suggested that more time to investigate the window mapping would be beneficial as there was a limited range of movement when standing directly at the display and this was cut short by new users approaching.

Social Organisation: Stemming from the honey pot effect, new users are attracted to points of interaction, but there are clear indications of implied rules around the shared interaction. New users do not approach too close to an on-going interaction as they reported not wanting to intrude, while at the same time on-going users were willing to share and adjust their position to facilitate line of sight. Between the two cases there were similar observed behaviours of users sharing windows, but also not encroaching too close, although this was more pronounced in the perpendicular case where distribution was greater.

In the parallel case the aspect of clustering had a marked impact on where users were standing and the "locking in" of on-going use. Where the density was higher there was less opportunity to avoid impacting upon an interaction, which could be seen in the response behaviour of on-going use. When asked, users reported not being overly concerned with sharing the space as it was understood there were limited points of interaction and so normal rules for personal space were lessened. While this was accepted, it was also reported that users would significantly prefer an individual window and freedom to interact as they chose.

Negotiation: Where exploration and number of windows was limited, "shoulder surfing" or "turn taking" would lead to users physically turning to identify position and the window of interest. Ultimately there would be small adjustments to allow clear lines of sight, but there would rarely be space made to allow this user to approach the display. These negotiations were seen to reduce the experience of those at the display, but were tolerated by those adjusting as they were sharing the “shoulder surfing” experience, however, this was unpopular as users felt “trapped” and “imposed upon”.

In attempting to avoid negotiation around clusters in the parallel case several users would leave significant space between positions and occupy the centre of the space. This would result in “capturing” approaching users between themselves and the cluster requiring further negotiation in the second row.

These two behaviours appeared to be related to the preference for investigation during approach, location within the cluster, and impact upon an on-going interaction. While there were several users who would repeat their behaviours across both trials due to subjective preferences, there were clear indications that users would change their behaviours based upon learning and investigation of the system influencing their intent to interact.

Learning and Investigation: During the two cases there was a clear distinction between users who had either engaged directly with the window interaction, or who had been able to observe the interaction by others such that the mapping could be understood. It was noted that where there was an understanding of the mapping of the windows this would influence how and where approach would occur relative to the configuration, either to achieve an individual window or to better support others entering the space after themselves. This goes some way to explain the changes in the approach behaviours of users between the two trials.

Those who were able to interact directly were also able to interpret the nature of the window interaction as being “hidden”, however, the depth relation between user positions could not be completely identified, although users were able to identify proximity as a key component. Users who had observed the window mapping were able to infer there was a relationship between positions, but had no concept of why windows would disappear or what this might imply between window and user interactions.

Feedback: The greatest indication by users was the inability to fully understand the nature of the system function. This was in part due to the design of the mapping and study design to assess awareness and learning, but also as a component of social organisations. For users who were able to interact with the content windows directly there were very few who could accurately identify the meaning of the “hidden” window interaction as the window would simply disappear. This would results in side stepping in attempting to get the window to remain visible, however, the secondary effect was that the windows would “flash” on and off, and users would assume this had some relationship to an action they were supposed to take. Ultimately this saw multiple users achieving a window and then remaining still to maintain stability. It was also reported that where users felt they owned a window they would like this to be clear and show a positive relationship to them.

For users who were not able to engage with a window they could not report on the mapping or interaction as there was no clear relationship between their behaviour and what was shown on the display. Instead users relied on the position of others and negotiation to achieve the task. These users indicated they would like additional information about their interaction and window behaviour so that they could make an informed decision about what was going on and how to respond, as any feeling of uncertainty around a new system left them feeling disconnected from the experience and was a negative impact.

Of all of the points raised by users through the first two trials, this outlines how and why users respond to aspects of the system and the space during interaction. Of the specific factors raised, learning appears to a have a large influence over approach and interaction. A greater knowledge of the system encourages exploration and widespread use and reduced confusion between multiple users sharing a single window. This was seen in the negotiations between users, where a more experienced users may be able to make a more informed decision about an interaction, so preventing the “shoulder surfing” and “turn taking” issues.

This seems to have an interesting relationship to Feedback, where users are attempting to understand the interaction of the system, and between one another, to be able to engage more fully with the content. The initial component of this investigation considered the entry position and deliberately limited the feedback to users, this now leads us to the second component of the study, where a greater consideration of feedback relative to learned behaviours and pre-conceived notions of the system are investigated.

6.3.3 The evolving nature of interactions with system Feedback

This section now considers how window interaction feedback influences the engagement between the two entry conditions. While the previous trials have introduced learning effects, users have reported that understanding and feedback are still critically lacking and there are many users who are not clear on the nature of the mapping or the windows interaction.

The within trial introduces an “animated” or “blurred” window interaction which maintains the position mapping with a change in scale where there is an interaction between two windows. Only the window of the users furthest from the display will be changed where there is overlap. This will leave the windows of the users closest to the display in their default state with the animated change taking place in their peripheral viewing area.

The final two trials will repeat the entry conditions in the same order as had been previously seen to maintain the counterbalanced consideration in addition to the window interaction. As both groups have now interacted with the system from both entry conditions it is expected that there is an equal level of understanding of the display and nature of the system. Each entry condition and factors of window interaction are now reported below;

6.3.3.1 Parallel

Entry order of participants was mixed such that the least experienced users were the first to enter. As expected the users moved immediately to the left hand end of the display, the landing zone, and began to cluster and engage with a limited number of windows. Within this behaviour there were indications of users investigating the mapping of the window, but more importantly the window interaction animation. Initially this played a two part role.

Firstly, where users were engaging with the windows and mapping there was limited engagement with the content or significant effort made to identify a location to interact. Instead users were investigating the interaction throughout their approach, occupying a larger space than required. This lead to the second issue of additional users entering the space but having a limited area to approach due to the movement of users in the cluster. This resulted in two further behaviours, with new users observing window interactions more easily due to the constant mapping and being visible in gaps, so joining the rear of the cluster, but also with users following the mapping and moving further to the right end of the display.

Those later to enter were the more experienced users and these were seen to be more pro-active in observing the new interaction but also investigating the remaining space beyond the cluster. Within these investigations, there were seen to be several factors of user interaction due to both feedback and the available gaps. This was still limited due to the actions of the novice users either investigating locally or being unsure of how to interpret the feedback, so giving an overall poor usage across the width of the display.

Distribution by more experienced users allowed for quick interpretation of feedback and its relation to others in the space. Where feedback was seen by on-going users there was initially little interest in sharing the local space or responding to the visible feedback. It was noted this caused an annoyance to the user experience of those at the display as they were already situated and identifying feedback from a user moving behind may indicate a need to respond or share their window. In many cases the approaching user would continue to the right, and even to the edge of the display, until they could find a location for a new window, yet this would cause consistent feedback between all windows already shown to the left.

For experienced users at the display they were able to interpret a "digital awareness" of the space around themselves, with clear glance behaviour to the side and behind where there were window interactions. This was later adopted by the novice users and used to help negotiate and situate themselves across the display where there was a wide enough gap for the feedback to be visible. This relationship between the display feedback and physical position of other users eventually saw those at the display adjusting their position to allow new windows to form, but equally allowed for a wider understanding of how multiple windows were meant to fit across the display.

While the cluster was relatively slow to separate through local organisation, once users were familiar with the meaning of the interaction the cluster was seen to separate out. This was a two part process of initially noticing users moving behind the cluster, with window animations of users moving right encouraging following behaviour, but also users behind attempting to occupy gaps in the landing area and "wedging in" by approaching animated windows being shown. This encouraged the use of feedback to further distribute the cluster away from these positions

This case has shown how entry condition can still have a negative affect where there is prior experience and improved feedback, with there being a significant impact due to continued clustering. Feedback was then seen to support local organisation where natural phenomena formed, either through a background awareness of potential for movement and exploration, local negotiation, and supporting a "digital awareness" for approach around gaps at areas of over distribution, or around users occupying larger territories seen in their exploration. The issue of digital awareness and the animated state were found to affect experience where window interactions were on-going and not related to an immediate interaction or requirement of the user, however, this was quickly identified and related to actions of others as part of learning and experience and mostly disregarded.

With the fourth and final interaction in this condition there was seen to be a marked learning effect for both entry and window interaction. As all users had been able to identify the window interaction and its meaning, the general behaviour was to approach the centre or left hand end of the display, followed by later users selecting the largest available gap to achieve a window and then utilise the interaction to maintain a stable window.

The entry condition appeared to have a limited impact upon this behaviour, with there being a preference towards approaching gaps closer to the entry point, however, this would be relative to the size of gaps available across the width of the space and was linked to the distribution of the first four users.

The general distribution of user behaviours between all eight groups (both conditions) resembled the following approximation (Figure 6-16):

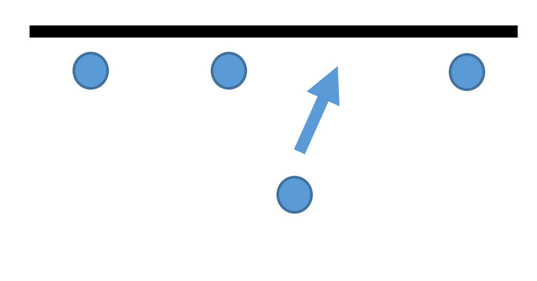
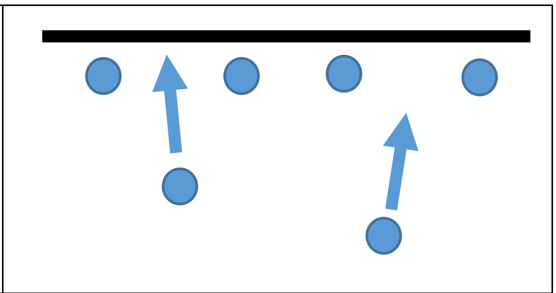
	
The first user would normally approach the centre or nearby, with the following two adopting wider positions leaving one clear large gap at some part of the display.	Subsequent users would move in to the largest of these gaps with some consideration for the distance from the entry position.

Figure 6-16: Showing emergent distribution of users entering from the perpendicular position after multiple interactions with the system and supportive feedback.

6.3.3.2 Perpendicular

As might be expected, the users entering in this condition followed a similar initial entry behaviour as seen in the first trial, however, there were several early exceptions as the centre of the space began to fill. With there being a limited number of novice users in this group, given early distribution and awareness from the previous interactions, there was a tendency for members to begin to distribute themselves across the width of the display and to avoid approaching on-going windows, or forming clusters.

When combining this type of interaction with feedback, along with the experienced users, there was a clear distribution of users across the display. This either saw users moving to extreme positions to have a maximised space, or moving deliberately towards gaps with the animated window to achieve a full interaction. This immediate distribution and relation to content windows gave an extremely strong sense of ownership to the majority of users and there was a strong understanding of where the user was and how their window interacted.

The feedback elements between users was quickly identified and explored by many who were distributing across the display. Again, the sense of digital awareness was present, with users turning to observe the movement of the window interactions and relating these to user movements. What was particularly pronounced with these groups was the ability to share the space and quickly organise themselves using the window feedback. Where the other condition had multiple issues with clustering and territoriality, this group appeared far more aware of the need to distribute across the display and negotiate for space.

There were still considerations of novice users either investigating aspects of feedback between windows, or approaching on-going windows and trying to form clusters, however, the feedback element quickly helped smooth these interactions. In several cases the result was that more experience user were able to interpret the intention of the novice user and adjust to support their approach. Within this there appeared to be considerations of how this might impact upon the wider use of the display and others windows in close proximity.

General movement in response to window interaction would move towards more stable areas of the display, reducing the overall footprint of window distribution, leaving the gap on the side where there were fewer users and creating a larger space for new windows.

This raises, perhaps the most interesting consideration of the trial, as this behaviour appears in direct contrast to the actions of the parallel entry condition. Where the other condition showed a limited faculty for negotiation, either within the forming clusters or after having struck out to establish a specific location, this entry behaviour appears to better support an understanding of the use of the space, further supported by the window feedback interactions. While all users have had the same number of experiences with the system and forms of feedback, the initial interactions and learning between the two conditions suggest that the perpendicular case offers a much stronger sense of how multiple users are engaging with the display and their individual windows, with greatly reduced social pressures and more space for identification of potential gaps during entry and approach.

With the final interaction with the system it was seen that users were very quickly able to establish a distribution across the display whereby all users could achieve a stable window, similar to how was reported in the final interaction in the parallel condition above (Figure 6-16). Again, this entry condition allowed early users to identify gaps and landing zones during entry and approach resulting in high levels of utilisation of the display space.

As additional users entered there were indications of negotiation and adjustments taking place via the appearance of new windows and the window interactions, however, there was a significant reduction in glance behaviour. It was generally seen that users could quickly interpret the appearance of the window, while briefly checking where space was available either side of the new window location before moving to allow the new users to enter. This resulted in a very streamlined process between almost all users at the display.

In both conditions there were examples of the sixth and seventh users struggling to achieve a full window where those at the extreme ends of the display had left a large gap between themselves and the edge. This resulted in remaining gaps not being sufficiently large enough to support a full window and introduced a marked effect on those attempting to make space. In turn this caused multiple dispersing interactions across the display as users shuffled along in an attempt to make space, but did not appear to solve the problem effectively, instead causing annoyance to those attempting to help.

6.4 Key factors of display feedback and user experience

There were several roles which the animated state and feedback were used for; helping to identify interactivity during approach especially for novice users, separating out clusters of users, identifying positions of others in the space, and helping to distribute users in achieving a higher number of MISU interactions. These are now further considered.

6.4.1 Identifying interactivity

By presenting users with a window when they are passing behind it is possible to quickly gain a connection to the display and the nature of the interaction, as described in mirroring, etc.. This was seen to support both entry conditions, but critically, aided in mitigating the clustering seen in the earlier trials. While learning clearly played a role, the ability to interact from initial entry and extreme range impacted the distribution pattern of users, in particular, novice users, who may not have experienced ownership of a window previously. By ensuring users are able to interact with the system as early as possible there is a more streamlined interaction and experience. This does raise questions of how and where the interactivity is shown and how this impacts upon those already at the display, as was seen in the clustered case with interruptions and distractions to on-going users through awareness of the windows, or due to users attempting to engage directly where they see the mapping but there is not space to form a window, leading to “wedging in” and further clustering.

6.4.2 Separating clusters

This proved to be a significant aspect of the feedback approach as it supported a significant issue identified in both entry conditions. Where users were quickly able to identify their individual windows and the interaction to others there was an organised movement of users to arrange windows to support those to either side. This did have limitations as it may not be possible to adjust sufficiently, or the window may be impacted upon in the attempt.

There were, however, two major issues with separation of clusters. The first being that users attempting to support those around them could not easily identify the best direction to move, especially in cases where there was a window on either side. This led to “grid-lock”, where several new users would require all on-going windows to move, yet there would be locations, particularly at the ends of the display, where it was not clearly understood or the user chose not to move. This would leave several users in the centre of the display with no clear direction to move and several windows not clearly shown. The second issues was exploration of the interaction leading to gaps, allowing “wedging in”. This proved to exacerbate the situation of clustering in those locations, although this was not overly critical. This nature of exploration and lack of wider interpretation of the feedback proved to limit the overall use of the display, as it was not immediately clear how this mechanism related to all users and the need to evenly distribute given the size of the display.

6.4.3 Identifying other users through digital awareness

The concept of “digital awareness”, whereby users could interpret the positions of other in the space both supported organisation but led to distractions. This included glance behaviour to identify a need to move or interact with another users, but also factors of movement behind clusters informing users of other position to interact and alternative approaches to engagement. This factor appeared to change in nature between the final two trials, with users not using glances as much but instead relying on new windows appearing and staying still to indicate approach and a need to move. This suggests a limitation in the current design, whereby the first experience does not convey sufficient information about the distance between users or a particular need to move being clearly shown. In the second instance users identified that the movement of windows is a distraction, especially given the level of learning about how and where to interact, and simply acknowledge the new window and adjust if it remains persistent at a given location.

6.4.4 Distributing users

The final outcome of feedback was to see users naturally distributing themselves due to a greater understanding of how multiple windows were interacting. While there were limitations due to the tolerances of the animation effect relative to available space, users were generally able to identify the optimal locations during entry to achieve their own window, where previously users had followed more simplistic clustering approaches and accidental discovery. While the distribution initially appeared a by-product of several factors of spatial behaviour, the range of information implied by the window interactions appears to support a significantly improved learning effect in both conditions, with the optimal distribution eventually achieved in both cases.

Understanding how the use of feedback both influences use and affects user experience presents a two part application of the approach. Initially, we can begin to apply feedback in a manner that will support and potentially alleviate natural phenomena which have a negative impact upon the use of the display. While the application of feedback can be limited based on user experience and the expected impact the application of adaptation can have given the nature of a user's on-going interaction. This now begins to indicate that feedback must either be tailored to a specific task given local factors, or interpreted through user experience as a product of changing layouts and feedback.

6.5 Considerations of system use and user behaviour

This section now considers the wider implications of this study and how these factors can go to inform the problem space within the context of responsive systems, as well as the requirements for the next iteration of investigation and system design.

6.5.1 Entrance position

There were clear implications of how entrance position influences the overall interactions of MISU's. The perpendicular case appears to be a far simpler scenario for users to assess and interpret the layout and nature of interactions of others in the space. While there were initial examples of clustering, the nature of approach allows users to naturally organise themselves in a manner which reduces, but does not totally remove the impact of this phenomena. The initial organisation of users at the centre of the display facilitated greater exploration and learning in early interactions, resulting in further exploration and distribution of experienced users in following trials, further supporting distribution and wider awareness between users. With greater potential for learning and exploration around the mapping, and additional feedback between users, effective organisation was possible with minimal negotiation.

The parallel entry position exhibited a significant number of issues with both usability and overall user experience. This entry position quickly led to clustering and a reported poor experience due to shoulder surfing. Even with learning and exposure to perpendicular entry there was little evidence of a significantly improved effect to either aspect. While learning effects did appear to influence the use of the system, the introduction of feedback still saw issues of social interaction limiting discoverability and use. This could potentially be linked to the initial learnt attitudes associated with entry and limited potential for exploration leading to territoriality in later interactions.

While both conditions exhibited clustering and ultimately showing distributed interactions, the parallel condition resulted in a very poor overall use case, with clustering behaviours still dominating the engagement. This can be linked to a reduced effort by users during engagement continuing to form clusters, but also individual preferences for where to engage being linked with learning and awareness of the overall system function. Where individuals have knowledge or see an opportunity for their own interaction, there are potential approach behaviours which do not best support other users, potentially due to the greater distance from the display and only a single edge for exploration, however, this may be isolated behaviours and have a range of impacts which were not identified here. This leads to considerations of why this entry condition is affected by these formations and how this can be prevented or related to the layout for better MISU interactions.

6.5.2 Awareness

With awareness influenced by entry position, emergent organisations further influenced local awareness within real-time observation and learning of both mapping and feedback. With later entry the influences of entry position to organisations altered how awareness of both the display and potential system function were achieved, with the perpendicular case allowing wider considerations of learned behaviours and interactions between users, while clustering in the parallel case reduced line-of-sight for exploration and limited the local potential for an understanding of mapping and window interaction due to locking-in.

While clustering is seen to be a negative factor due to shoulder surfing, the potential for awareness of both mapping and window interaction offers a learning potential to influence wider use. The context for learning, via an initial awareness being formed in the emergent formations relative to entry and in observation of experienced users in exploration, is seen to alter the later approach behaviour between the two entry conditions as awareness emerges from both the actions and densities of local organisations, but also actions identified. Ultimately reduced learning, clustering and poor positioning reduce potential for awareness of both mappings and window interactions which go to improve decision making.

This points towards a need to improve feedback or initial distribution of users to better support wider awareness and potential for local landing and learning during entry, with the parallel condition significantly suffering from these issues.

6.5.3 Social Organisation

Initially social organisation developed out of necessity where there was limited awareness or understanding around the interaction. The nature of organisations were found to be related to the entry condition, with the perpendicular case offering greater awareness and opportunity to explore allowing for looser formations and in clustering and shoulder surfing, whilst the parallel condition saw enforced clustering and denser organisation as users shoulder surfed in sharing fewer windows. The nature of these organisations then went on to influence learning around the interaction and relation to the space.

Where organisation was influenced through requirements to interact, social boundaries were softened as users accepted the limitations in potential access to shared points of interaction, although this would have ideally been avoided during use, particularly by those who had initially identified a window and were experiencing the interaction. As a direct relationship to experience and the nature of learned interactions relative to entry position, forms of social organisation were seen to change between trials based on the initial entry condition, with perpendicular entry tending towards isolated experienced users and lower clustering, while parallel tending to see higher levels of distributed local clustering.

With additional experience and learning the parallel condition still experienced clustering as factors of both reduced approach given entry position and awareness for potential approach towards a distributed social organisation and its meaning, with wedging in being seen compared with wider exploration and awareness in later perpendicular cases. This gives strong indications that supporting feedback or adaptation to support exploration and discovery would be highly beneficial for novice users in the parallel scenario

6.5.4 Negotiation

Negotiation was initially related to social organisation to allow line of sight and personal space. In the early trials the lack of feedback led to physical awareness and negotiation between users sharing content windows. This led to distracted engagements and poor experience, and was better addressed once feedback was introduced to provide an out-of-band mechanism to infer social interactions through a digital awareness. Greater learning reduced the need for physical and social organisation as users could assess the needs of multiple users interacting locally and adjust towards a state of achieving a stable window, however, the initial need for glance behaviour to identify a window-social relationship distracted from the experience and could have been supported through improved feedback.

While social interaction and negotiation is a component of any experience within the Ecology model, there are many examples where this is not ideal, such as long running interactions or cases of personal preference. While digital awareness was used by experienced users to support approach towards a more stable local organisation, wedging in added an implied social pressure to the display. While this was utilised in both entry conditions, identification of larger gaps in the perpendicular case reduced the impact over the clustered entry of the parallel case. Where wedging in was applied there were issues around edge effects of both the display and clusters, where limits of propagation and a lack of local contextual awareness resulted in grid lock and frustration.

Where feedback can support a minimised need for negotiation, there are also factors of adaptation or reduced feedback which may better address the on-going interactions to minimise the need for negotiation. Limiting the applications of spatial feedback around given locations and organisations would then act to reduce approach and interruption.

6.5.5 Feedback

In both entry conditions feedback encouraged localised distribution of windows and eventually supported an improved overall distribution. In both examples there were alternative issues preventing the maximised use case, such as social or learned behaviours and edge effects, with feedback supporting learning of system function. Perhaps most importantly the feedback of windows interactions and greater awareness of the perpendicular case offered a further level of social interpretation and exploration during entry, where feedback allowed consideration of gaps and not just window interaction.

The selected approach to feedback presented issues for those at the display where it was shown in the peripheral area of on-going windows, leading to the digital awareness phenomena. This presented a distraction and led to physical awareness and potential negotiation, which would ideally be avoided by a more streamline or informative feedback approach, and could be supported through local and on-going adaptation towards stable organisations. The freedom for users to position themselves in the space led to the display being under-utilised due to local issues of contextual ownership, with feedback being required in on-going use to aid in distribution.

Alternative forms of feedback could help prevent interaction with on-going windows where the window is in an ideal position and interaction would not be beneficial. Alternatively removing feedback in given situations to prevent negative impacts to on-going use, or applying pro-active forms of feedback to encourage more general spatial behaviours may better support the overall use.

6.5.6 Ownership

Ownership was seen to be one of the major driving factors in interaction, investigation and negotiation between users. Those who were able to experience a single content window and investigate the interactivity of the system reported a strong sense of ownership and connection to that window. This encouraged users to either move away from clustered areas to achieve or maintain a window. Users in localised clusters were happy to share their window for both interaction and testing of functionality, but there were inherent behaviours and zone of use that users aimed to maintain and did not like when there were intrusions. This was pronounced in the initial lock in scenario where stability was critical as this applied pressure on the mapping and position of the users in providing a shared point of interaction.

Ownership was initially established during entry and investigation of the mapping, either through movement or standing directly at the display. This would suggest that areas where users are free and have time to explore the display or factors of feedback are critical to the ownership process, this is important as earlier trials had identified the concept of ownership encouraging movement via adaptation. This is a significant issue due to clusters, even where constant mapping and feedback are shown as this leads to interruption and potential wedging in. Instead considerations of altering the form and position of feedback could support initial ownership without impacting locations and organisations of users, where adaptation may be a more beneficial mechanism to structure the space.

It was also reported that some form of ownership confirmation would have benefited the experience and may have helped to reduce approach and shoulder surfing by more clearly conveying the state of the window. Where these actions occurred, users who had initially experienced ownership through mapping were particularly influenced in their experience as they felt they had lost an aspect of ownership where the mapping was lost, either through grid lock or pressures of needing to maintain a stable window for co-orientation.

6.5.7 Summary

Between the two entry conditions there are clear implications for both natural organisation and interpretation of system behaviour in how MISU’s choose to engage. Where both cases saw issues of clustering, the perpendicular case seems to more readily resolve itself and is better supported by factors of feedback. While feedback did not prove completely effective due to a requirement to learn the nature of the information, there were indications that the mechanisms aided in social organisation to reduce issues of clusters in both condition.

Between each of these factors there are several which proved to be most influential in the user experience of both social organisation and feedback. In both cases, presenting landing areas and allowing for early learning and ownership gives a clear understanding to users and boosts overall competence and engagement with the system. This factor was seen to be limited, especially in the parallel condition, by factors of clustering as a natural phenomenon which was seen to be negative for both user experience and use of the display. Clusters not only reduced landing areas, but further stressed a need for social interaction and negotiation. As such, there are several considerations towards the design and implementation of these findings in better supporting MISU interactions with these systems.

It seems as though a mechanism to dissolve clusters as they are forming, or users actively moving away from the landing areas as demonstrated by more experienced users, can work to both reduce issues of negotiation and overbearing feedback while supporting novice users in their initial engagement and ownership. As users moved into distributed configurations, as was a more natural case in the perpendicular condition, the more systemic issues of the parallel case were alleviated, however, awareness of potential gaps and approach within the distributed organisation is reduced given the entry position and reduced effort and expectations in initial learning. Given the two conditions, it now seems that the parallel case presents multiple complex aspects of natural behaviours which do not lend themselves to the natural organisation and simplifications seen otherwise, and so should be more thoroughly considered to identify wider ranging solutions for both conditions.

6.6 Simplifications

Based on the findings of this study there are several simplification and areas of focus which can be more actively pursued in identifying the role and nature of layout changes on displays when considering MISU interactions. These now include;

- Focussing on natural phenomena around interactive displays, in particular clustering and negotiation between users and identifying how these can impact upon user experience.
- Removing the perpendicular entry condition and focussing on the parallel condition, as this was seen to induce natural phenomena in the presence of feedback as a matter of the learnt nature of the experience itself.
- Consider how changing layouts can shift users between the clustered and distributed configurations as seen in the more effective use cases of the display.
- Identify factors of leading or movement behaviour in presentation and feedback to encourage more effective use of the display.
- Develop early entry strategies focussed on novice users which encourage landing areas, ownership and exploration of the system.
- Consider how various approaches to changing layouts can be applied in various use cases.

With these in mind there is now a strong basis to consider how system led layout changes can be applied to not only infer the role of the display in user behaviour, but also to address the user experience at all levels of use. This presents the case of mapping display changes to use cases and behaviours in space in an informed manner for later investigation.

6.7 Contribution to knowledge

This study has now addressed sub-question two of the research question;

2. Develop a system capable of evaluating a range of layout and presentation factors for MISU interactions to inform the use of these factors in natural behaviour.
   a) What are the minimum requirements of a system to evaluate a real world scenario?
   b) How do aspects of entry and feedback influence the natural use of an interactive display and what is the impact upon user experience?
   c) Which factors of layout adaptation can be related to approach behaviour and on-going display phenomena?

Building upon the findings of the Literature Review, Field Work, and Study 1 - Wizard-of-Oz, a series of system requirements were derived to address the overarching considerations of MISU interactions with and around PLID's. These were reiterated in the introduction of this chapter, along with the design and development approach in creating the digital system to provide the minimum requirements of a system to evaluate a real world scenario. This initial development has now answered the first sub-question of objective two and provides a novel mechanism for the investigation of MISU phenomena around large digital displays.

This work has also investigated how entry conditions and feedback influence user experience. This has shown where natural phenomena exists which mitigate the effective use of these systems in ways that were not previously understood. This has now answered sub-question 2 of objective two, and presents a body of evidence and simplifications for an investigation of system driven adaptation relative to on-going natural formations.

With this in mind we can now consider supporting greater numbers of users and on-going user experience around displays through exploration of emergent organisations in a way that is not currently understood, giving a series of informed relationships between phenomena of use and further areas of exploration in moving towards more optimal learned use case conditions. This goes on to answer sub-question 3 of objective two, to present a clear area of further investigation. This will now be laid out in the following chapters.

Having considered the role of entry position and display presentation, specifically content window interactions, there are clear implications towards how these types of systems can and should be used relative to a Responsive System given the situation and use cases of the display. Where there are indications that many previously identified factors of display interaction are entirely related to the awareness and understanding of users, there are also considerations of learning effects in mitigating these factors. This leads us to consider; how learning can be facilitated in MISU interactions, and considering the role of system behaviour in supporting and mitigating these scenarios in novel manners.

Continuing this approach we can now consider how, when and why a digital system can applying changes to layout based on user behaviours. This is addressed in the following chapter.

Chapter 7: Study 3 - Adaptive system

This chapter now begins to bridge the findings of sub-questions 2 & 3 of the research question as part of the investigation of system led adaptation in the natural engagement of MISU's with PLID's. The chapter will consider the following points;

- How are natural formations of users and user decision making related to system led adaptation during entry and approach.
- What are the leading factors in user decision making and user experience when considering display feedback, social interaction and adaptation.
- How and when are adaptation strategies appropriate, based on user experience and the physical space.
- How effective are these approaches in supporting on-going use and how does system led interaction influence the overall use of the system.

This will be addressed through the second iteration of MISU interactions with considerations of on-going user configurations, adaptations of the display layout, and the effect this has during user approach and engagement. This extends the previous investigation by relating the emergent formations of on-going use to informed adaptations of the layout found in optimal learned behaviours for greater display use.

The critical findings of this study will relate both supporting and mitigating factors of display adaptation to the behaviours and experience of users, situating the role and understanding of factors of adaptation to the wider understanding of social-spatial display interaction. This is presented in two stages; firstly, the considerations of the previous study and simplifications of the factors of display use in constructing informed display adaptations, and secondly, the design and implementation of the investigation of these factors. In all, this will consider the design of the investigation, data capture, findings and analysis.

The previous study has identified two critical aspects of display behaviour that influence entry and engagement during MISU interactions, these are; the influence of the configuration of on-going user at the display to decision making during entry and approach, and how natural approach behaviours can influence the interaction between MISU's at the display. Where changes in presentation and layout have previously been shown to influence interactions at displays, this has not currently been related to the wider question of interaction behaviours between users. This now leads to considerations of how adaptation of layouts can be informed through observed emergent behaviours in achieving greater utility of a display, and how these are related to on-going configurations and user experience in understanding best practices in application of adaptation in supporting approach behaviour, interaction between users, and user experience.

This leads to a two-fold consideration of how adaptations might be used:

1) How can adaptations be applied in an informed manner to influence natural formations to better support entry, approach and wider engagement.
2) Can adaptation influence real time behaviours and learning relative to entry and awareness to support more immediate engagement and improved user interpretation and experience.

The chapter now goes on to discuss the interpretations of the previous findings in identifying emergent behaviours of user engagement, along with the learned behaviours which supported them. Further to this, the findings will be used to develop several adaptation strategies relating factors of entry and approach to configurations of use.

This will be presented in three stages, with simplifications of the critical factors of the Responsive System related to system requirements for the adaptive system, this is followed by the design of the adaptation strategies relative to natural engagement behaviours, and finally implementation of the study design and results found. This process is now detailed.

7.1 Simplifications

Findings from Chapter 6: Study 2 - Responsive System, identified several critical aspects of natural behaviour relative to forming configurations and the engagement behaviours of new users during entry and approach. Along with these critical elements there were several secondary aspects of behaviours which influenced the nature of entry, awareness and approach. These factors are now considered to relate the previous study to this area of investigation;

7.1.1 Entry behaviours and emergent formations

Entry Conditions: Both conditions saw issues of emergent clustering limiting utility, however, the perpendicular case saw a far greater improvement with the application of feedback and learning effects in overall distribution. As such any small or localised changes through the application of adaptation would likely result in a significant improvement in the overall use of the display in this condition, specifically maintaining a landing area at the centre of the display. The more pressing issue was the continued clustering seen in the parallel condition, even with the application of feedback and learning, resulting in a poor utility of the display. As such, this investigation will only consider the parallel entry condition and the role that adaptation can have in supporting the more prevalent issues found in natural organisation.

Clusters: Clusters, or clustered configurations, are clearly defined through grouping or “Honey Pot effect”, related to awareness and natural curiosity. While this is a major influencing factor in socio-spatial behaviours there is a significant impact upon MISU engagement due to the lack of a landing areas and reduced investigation through direct interaction leading to “ownership”. Feedback through widow interactions influenced this phenomena, but at the detriment of consistent user experience. Learning effects and awareness were also seen to influence the formation of clusters, however, this cannot be relied upon, as novice users and limiting factors of configuration can reduce the overall awareness of the display. The role of adaptation relative to clusters or a “clustered configuration” will be one of the main considerations in this investigation.

Distribution: Distribution of users was seen through learning, movement and window interactions in emergent maximised use. This resulted in a combination of the “ideal use case” in utility of multiple users evenly spread and able to engage with individual content windows, but also introduced issues for new users not being able to identify or explore the interaction, leading to renewed clustering. Within this configuration it is unclear how novice users may interpret gaps or landing areas and how changes in presentation or layout may support approach. The role of adaptation in supporting entry and approach within a “distributed configuration” will be the second main consideration in this investigation.

Targeted approach: Through learning of system behaviour and window interactions experienced users were able to “target” larger gaps in achieving a window, avoiding issues of clustering and leading to examples of the stable distributed condition. This presents an adaptation strategy to encourage approach towards available gaps through feedback via a new window and localised adaptations of on-going users.

Landing area(s): Described in literature, landing areas are extremely important in the identification and exploration of system behaviour for novice users. Those who engaged with landing areas, particularly early in the trial, developed a greater awareness of the system and strategies to achieving a window interaction. A secondary adaptation strategy will aim to maintain a landing area relative to the entry position via adaptation of on-going users.

7.1.2 Secondary Factors

Ownership: Direct interaction with a mirrored or “responsive” content window was one of the strongest indicators of the potential for applications of changing layouts. Where users were aware a window was linked to their movement, there was a clear intention to maintain that interaction, even where others were attempting to engage. Users would share windows but did not want to lose the interaction and would act accordingly. This suggests that a perceived ownership is critical in adaptation directly influencing the behaviours of users. This has been shown in literature, but not yet in the context of relative adaptations between MISU interactions. Users must be encouraged to form a responsive interaction with a content window in garnering a response as adaptations take place.

Feedback: Feedback in the form of window interaction gave a greater awareness of local organisation, allowed for a “digital awareness” of movement, and supported awareness of the interaction during approach. Each of these factors encouraged awareness, interaction and exploration leading to greater use. The limitation was seen in windows being presented and interacting where there was insufficient space i.e. behind a cluster, causing issues to on-going use and a “wedging in” effect through novice users engaging with the cluster. This form of feedback will be maintained throughout the study, but will take the form of a large ovoid “position marker” along the top edge of the display. Markers will each have a unique colour to indicate individual ownership, and windows will only be shown where there is a sufficiently wide gap to allow a full window to be shown. The window interaction will only be shown for windows in the responsive state, with windows that have been moved during continuous adaptation changed to an “adapted” state and being fixed in position.

Movement: The influence of bulk, or on-going movement was seen to influence decision making during both entry and on-going use through a physical and digital leading effect. During entry, on-going movement, usually exploration and targeted approach by experienced users, would encourage emergent approach behaviours outside of natural clustering. These same actions would also encourage separation and exploration within clusters due to digital awareness. Understanding how movement stems from adaptation and its role within user experience will help interpretations of applicability of adaptation.

It is important to note that these behaviours were generally identified when there were four or more users interacting with the display, as this constituted the maximum number of users interacting on one side of the display, and so a full cluster. These clusters were small enough to allow interaction but were also sufficient to draw new users in. Four was also an appropriate number during distributed cases, as this would leave both sides of the display appearing to be occupied whilst also leaving sufficient gaps for new users. As such, the on-going configurations and adaptations will consider there to be four users in the space followed by three new users entering and triggering adaptations.

By considering the learned behaviours of experienced users in avoiding the stated issues it is possible to construct adaptation strategies to account for the above factors.

7.1.3 Developing Adaptation Strategies

With the above points considered we can now outline the design for the adaptation study:

- Remove the Perpendicular entry condition.
- Specify the Clustered and Distributed configurations to assess the effectiveness of adaptations in these scenarios.
- Employ adaptations based upon observed natural approach behaviours related to experience to support novice approach behaviours.

With the following adaptation strategies being applied:

Targeted – The new window is created in the largest available gap across the width of the display, in-keeping with users approach behaviour in the previous study. This aims to draw users to locations via feedback to assess how effective they may be in maximising utility.

Constant – All windows are adapted to the right end of the display creating a "landing area" at the entry position. This also considers influences of leading effects in entry and approach.

Both strategies are applied to the Clustered and Distributed configurations to explore the differences in the local and global behaviours.

Two overarching considerations for the effective use of adaptation will be:

1) Supporting new users in their entry and interpretation of adaptation aiming to ensure each user can achieve and maintain an individual content window, preventing clustering and maximising utility.
2) Maintain on-going users experience and investigate the role of feedback and landing areas based on layout and on-going use.

The following section will consider the design and implementation of the simplifications to the system. This will then be followed by the study design, implementation, and findings.

7.2 System Requirements

This section considers the specific design and implementation of the adaptation strategies, along with required changes to the supporting system. The two strategies are the "targeted" and "constant", with each addressing different aspects of entry and configuration.

7.2.1 Adaptation Strategies

Targeted: This strategy locates a new content window in the centre of the largest available gap as the new user enters. Where the gap is not sufficiently large enough for a new window the adjacent windows will be adjusted as required to situate a full sized window. This strategy considers how users entering assess the current layout and maintain an awareness of display changes. The window will enter the responsive state when the user is directly in line with the window, allowing adjustments in position for ownership. The diagram shows how the targeted adaptation is applied to both the clustered and distributed conditions (Figure 7-1):

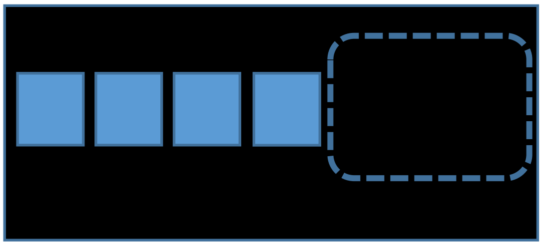
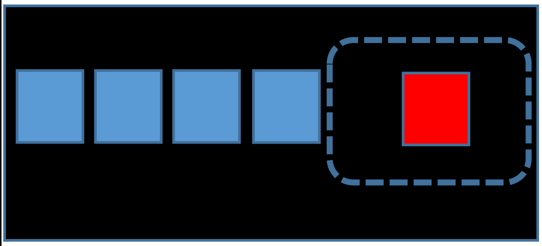
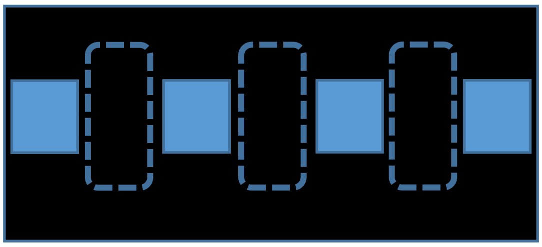
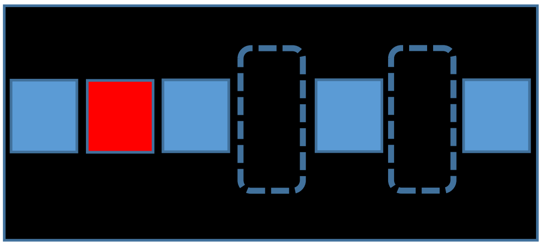
CLUSTERED	
	
The clustered configuration with the largest gap indicated by the dashed line.	As the new users enters the new window (Red) is shown in the largest gap and will enter the responsive state when the user is in line.
DISTRIBUTED	
	
The distributed configuration with all available gaps indicated by the dashed lines. The gaps are not uniform, but are determined by the positions of those already at the display.	As the new users enters the system selects the largest gap and presents a new window (Red). Where there is not enough space the adjacent windows are moved outwards as required.

Figure 7-1: Showing the changes in layout as the result of the targeted adaption in both the clustered and distributed configurations.

The largest gap was selected as this was the predominant behaviour of experienced users when entering the space to achieve a content window in both previous conditions. If the approaching user does not identify the window and selects an alternative location, the window will remain for a short time, allowing them to explore the display and possibly identifying the window, before the window is hidden and the position marker moves to their current position with the window then being shown in the responsive state. This strategy test both the decision making and awareness to change as users enter the space.

Constant: This strategy takes all content windows and places them at the far edge of the display as the new users enters. The aim is to present a clear landing area and suggest a general movement or flow in the space, while also assessing the minimum requirement for a new users to find a gap as the display fills. This will also assess how configuration and movement influence on-going users. Once the adaptation has taken place, all windows that have moved will be fixed in position showing the position marker above. New users are presented with a responsive window that will remain in that state until another adaptation takes place and their window is moved to the right and fixed in position. This can allow the users to explore the space and interaction as well as considering the movement of on-going users. This strategy will act as follows in both configurations (Figure 7-2):

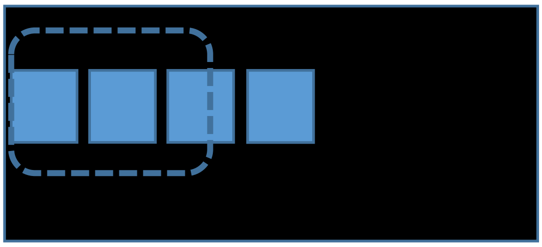
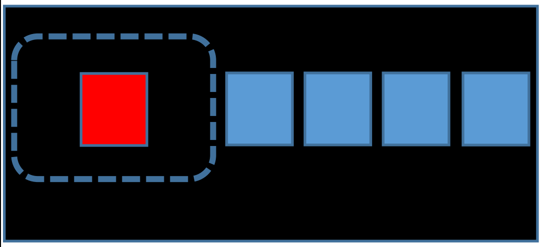
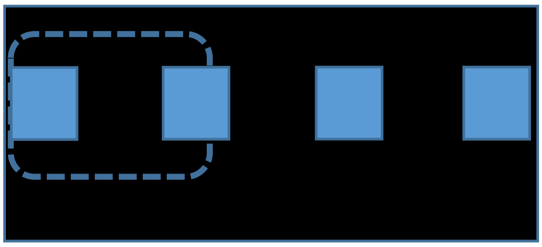
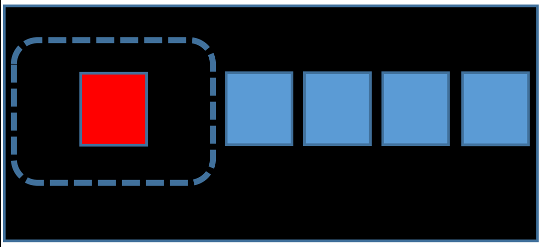
CLUSTERED	
	
The clustered configuration with the landing zone indicated by the dashed line.	As the new user enters all windows are moved to the right and the new window (Red) is shown in the responsive state (mapped to new user). This is repeated for each successive user, with the available space being reduced each time.
DISTRIBUTED	
	
The distributed configuration with the landing zone indicated by the dashed line.	The result is the same as above.

Figure 7-2: Showing the changes in layout as the result of the continuous adaption in both the clustered and distributed configurations.

In both adaptations strategies the system selects the location to place all adapted windows, with both cases utilising different approaches to placement. The constant adaptation places the adapted windows at 1/7 the total width, to allow all windows to fit with only the newest window needing to be adapted with each new user. The targeted adaptation only adjusts the windows which are immediately required to move to allow a new window, distributing them evenly in the minimum required space, up to and including the width of the display if necessary. This minimises impact to on-going users but may result in the same on-going user experiencing multiple adjustments as the system aims to accommodate seven users.

7.2.2 System Development

To account for the adaptation strategies, several changes had to be implemented in the software;

World state: The world state variables handled by the Data Processor module considered the thresholds for the number of users in the space before triggering the adaptation, ensuring there were no false positives resulting from environmental conditions or tracking errors. A short time delay was applied to capture these factors before the “new”, or post-adaptation world state and positions were calculated based on configuration and adaptation strategy, causing windows to adapt.

User updated location: This represented the calculated position of each user in the space after the adaptation and was used to handle display changes and "errors" in user response behaviour, such as approaching the wrong location. This allowed the Display Handler to return responsive control back to the user when they stood in front of their window, or to move windows back to users who did not respond. This was only applied to the results of targeted adaptations as constant adaptation position would remain fixed.

Content window: Windows were updated with a state "adaptation required", and internal variables relating to post-adaptation position and user position to recover the "responsive" interaction. Finally, where users did not return to an adapted window an internal timer enabled the window to remove itself from the display and move the position marker towards the user's current position, preventing windows traversing the display causing distractions.

Display Handler: Where adaptations took place there were multiple variables which had to be accounted for, including updated position, required presentation width, adjustment to adjacent windows, movement speed, etc., as well as window interactions during overlap considered in the previous study. The solution required dynamic stacking of content windows based on user depth from the display to ensure correct presentation, before then inserting the new window and applying movement. The internal drawing state within the Content Window objects were then compared to adjacent window before drawing.

With these aspects of the system considered the design and implementation of the study is now presented in the following section.

7.3 Study Design and Implementation

This study consider the role of adaptation during entry, approach, and on-going interaction of MISU's in configurations identified in the Responsive System study. The factors addressed in the study are:

1) Configuration – Clustered and Distributed – These are the natural organisations of users at the display, seen through varying entry conditions and relative states of learning and emergent interaction behaviours.
2) Adaptation strategy – Targeted and Constant – These strategies account for the two main requirements and approach behaviours identified in the two configurations.

The study has two distinct components, with the first requiring several users from Study 2 – Responsive System, taking on the role of those at the display to form the configuration of users. This is done to maintain consistent configurations by separating their prior experience of the interaction from novice approach behaviours, but also to directly investigate the user experience of adaptation as a new aspect of the on-going interaction. The second component considers the response of novice users entering the space with no prior experience.

To prevent users being over exposed to adaptation immediately, the Targeted approach will be applied first to the Clustered and then the Distributed conditions. This will assess how adaptation can directly impact the Clustered configuration which was seen to be the critical issue within the previous trial. Secondly the Constant adaptation will be applied to both the Clustered and Distributed conditions. Users will not be informed of the changes and allowed to assume any similarities, however, they will be briefed before that there is a significant aspect of the interaction that has changed. This should ensure users are prepared to engage with what they are shown and not pre-conditioned or expectant of any particular feature.

Content in each window is displayed on a timed loop. After each timeout a new page of text is shown to allow users to continue reading and maintain focus on their window. This was set to around 15 seconds per page, keeping the interaction engaging.

The trial will not be carried out in a between and within format as the impact of seeing both adaptations would reduce the effectiveness between configurations. Instead, the initial focus is on how the system might encourage novice user approach based on the derived strategies. Following this the second consideration will be around how the system can influence larger movements of users to allow more natural discovery via the landing area.

As such, all groups will interact with the system in the following configuration;

Trial 1	Trial 2	Trial 3	Trial 4
Clustered - Targeted	Distributed - Targeted	Clustered - Constant	Distributed - Constant

Table 7-1: Showing the order of configuration and adaptation combinations.

Before the study repeat users were briefed on the required configurations. The users were not told why or what would happen, but this ensured that the correct configuration was achieved. These participants were also included in the final interview, with their resulting experience being used to inform the concepts of adaptation to on-going experience.

For each trial the repeat users would be given a configuration with their entry order mixed between trials. This was done to ensure there were no tendencies between participants in selecting locations and each experiencing a range of factors. The three novice participants would then mix their entry order before entering. Once the configuration was achieved the novice participants would be asked to enter the display space at five second intervals.

In the same manner as the previous study, the investigation was repeated four times with different groups of 7 participants. Video data was captured with key points of interest noted by the researcher. A semi-structured interview was carried out with the entire group after each trial, with all participants being asked to describe their experience and what had happened. This was then followed by the critical points being directly addressed, either at an individual or group level. Any points of interest raised by the participants would be opened up for discussion throughout and noted down for the final debrief discussion.

7.4 Findings

This section now considers the findings of this study. Due to the volume of data captured the findings will be presented as a series of abstracted representations and on-going key points of the four groups interactions. These will describe the evolving nature of the interactions and influences of the system in user behaviour. The results as they currently are can be found in Appendix [E1 Transcripts].

The following sections will consider;

- The response to the targeted adaptation in both configurations
- Critical aspects of the targeted interactions
- The response to the constant adaptation in both configurations
- Critical aspects of the constant interactions
- Considerations of adaptation relative to entry and on-going use

Each of these sections will now be presented and elaborated on in terms of the effectiveness of the strategy and the experience of users relative to the overall interaction.

7.4.1 Response to the Targeted adaptation in both configurations

The targeted interactions tested two main considerations, with the first being how novice users have awareness of changes to the layout during entry and if this might influence their behaviours towards a more experienced approach, and secondly, how do localised adaptations influence the space and on-going use.

7.4.1.1 Clustered - Targeted

In all cases of the novice users entering the display space all are seen to approach the gap on the right hand end of the display as a part of their entry. Most users move directly towards the centre of the gap, with a limited few approaching the centre of the space to engage with the right hand end of the cluster. In almost all cases the first users to enter report seeing a new window appearing as they are about to stand in the gap, and so their decision is reinforced and they begin to interpret the nature of the interaction and the content.

There was a single scenario of the first user not identifying the new window. The user instead selected a location to the right of the cluster but did not investigate the gap itself. As additional users entered the first user becomes aware of the adaptation and identifies their own window. As additional users entered the space the result was for the majority to approach the available gap. Where this intersected with the cluster there could be a short amount of time taken to assess the windows shown to the cluster, but the new window would be identified and approached.

While the adaptation proved effective at supporting the first user there were several interesting factors of later entry. The majority of secondary and tertiary users were able to easily identify the available gaps and the appearance of a new window, or at least an available gap with a free window being shown. Issues arose where users interpreted their position based on the entry order of the new users, and so expected to remain in this order, making their interpretation of the layout confusing until ultimately identifying their window. A separate issue of adaptation was with layout changes taking place while users were not focussing on their window. This only occurred for the new users where they became distracted during targeted adaptation and they would have to re-interpret the layout.

The majority of user interpretations suggested a sense of being placed, but for a number of different reasons. Many indicated that the cluster had been placed there, and so it seemed that the system wanted them to approach the gap and that the cluster was separate from their experience. A greater proportion, however, suggested that windows were created as they entered and so there was a clear direction for them to go. The final suggestion was that users entered and made their own decisions about where to stand before a window would become visible and this would reinforce their decision, or in some case change their decision where they were engaged at the edge of the cluster. In each case the users entering the space suggested that the system was in control of the layout and was either supporting their decisions or suggesting locations to interact.

There were two main limitations reported by approaching users, in particular the final user to enter the space. Where new windows were created, the overall distribution did not appear the same for the final user, as the system only required the minimum space to be available or created to insert a new window. While these users were able to identify their window being created, in several cases the final user would remain significantly behind the line to consider the distribution of the three windows to the right in relation to the available space. They did not relate this distribution to the cluster, as this was extremely dense, instead the issue lay with the new windows and a feeling that there should be a fair or equal spread of windows on the right hand end if they were to join in. Users were seen to approach this issue by using the responsive state to apply gentle "pressure" between one another to encourage negotiation to allow the three windows to sit comfortably on the right hand end.

The second issue identified was with flickering in several windows across the display. This was particularly highlighted by the on-going users who found the flickering a distraction, even when happening at the extreme width of the display. Flickering was the result of users repeatedly moving back and forth across the threshold of the animation state, and was seen between multiple users across the display. Although the effect was usually seen in the new users as they were more dynamic in their positions and less experienced with resolving the issue, there were examples with on-going users being tightly bunched to the left.

The on-going users reported several experiential issues with the flickering. Initially the level of distraction this caused meant users would have liked to have moved around the space, or at least been given more space to help prevent the issue if they had not been asked to maintain a fixed position. Several users suggested they would have asked the rest of the group to move, but they did not know them and so felt uncomfortable. Generally the group would quite quickly resolve the issue themselves through adjustment. A further interpretation of flickering at the end of the cluster was that they would have to share as new users were entering and flickering was taking place.

Of all users who identified the flickering there was a general response to adjust position relative to the issue to either alleviate the issue, or allow more space for the user to solve the problem. Of the users that reported having a flickering screen, the interpretation was that the screen was actually "juddering" side to side, and so suggesting that they needed to move back from the display to stabilise the window. Although, several users did also report side to side movement as part of an investigation in to settling the window, this interpretation is interesting as it suggests feedback is conveying information about personal relation to the window and not to other users.

7.4.1.2 Distributed – Targeted

Across all trials new users were seen to enter the space and approach the first gap on the left. As on-going users were equally spread this was approximately the largest gap and was certainly the easiest to access. In all but one case the users immediately received a window, with the last window being shown in the third gap, which was not identified, and the user standing and waiting. As the secondary users entered there was a shift in approach towards the right hand side, with only a single users approaching the centre. This may be due to the first user approaching and adjacent on-going user making a small shift to the right reducing the space in the centre, although the initial configuration may not have been entirely uniform. In all cases, the users entering reported that the layout specifically encouraged approach, usually to the largest gap as this would often seem the most comfortable position;

> "I walked in to the nearest space available that was big enough then I waited …"
>
> "There was an empty space so I went there – I didn't feel like I was guided, it was the space."

> “The rough area was mapped out by the physical constraints – it was pre-determined – I knew where I was going to slot in. Another window popped up in the space ...”

During the initial approach there was little identification of windows appearing and leading users to the location. It was generally considered that users were forming a quick opinion around the use of space and then responding to windows being shown as they approached. In the case where there was no window shown the user waited several seconds with no intention of moving or showing awareness to the remainder of the screen.

There is evidence to suggest that the early adaptations and movements on the display can cause leading effects and inferred movement of users at the display, eventually leading to wider issues. A strong indicator of this was where the window was generated in the third gap and then returned to the position of the appropriate user, there was seen to be a general shifting left of those in the centre as the overhead position marker moved past. In turn this increased the width of the right hand gap and directly encouraged approach in this case.

Where small adaptations were seen with windows being created, on-going users were quick to respond by following their windows to maintain an ideal reading position. This had some restrictions, with users wanting to limit their movement due to the impact this might have;

> “I thought it was going to merge with another window because of the animation – when the window moved I wanted to follow it because I wanted it back”

> “I don’t think I would have moved anymore … then I would be invading their personal space”

While these factors were readily resolved in the local area, with users reporting not being concerned with people being too close as long as they could maintain a stable window, issues arose where there was uncertainty in the movement of windows or position of others. The most significant issue for on-going users was identifying that there were additional users in the space, but not clearly knowing where they were in relation to their own interaction. Where window interactions were resolved through small adjustments, in many cases users would indicate they had searched for the position of the person who was using the new window. This was an issue for two reasons; trying to actively identify new users and move to support their approach would limit awareness of adaptations while their attention was drawn elsewhere, and where adaptations then took place there was a feeling that their interactions were being pushed aside to make space.

This was further compounded by the content delivery, with content moving across the display and changing on a timer which left users feeling pressured to engage while also considering the wider space. In many cases this led to users backing away from the display to try and re-capture control of their window and to give an awareness of the display space;

> “There were a lot of people moving around so I moved back and forth to try and find a sweet spot where I could have my window.”

> “There are several issues with the content – it is moving, or being pushed by somebody behind you, but it is also on a timer – it makes it very hard to engage with the content because there is so much pressure – There are other people moving behind you …”

This breakdown in the formation was a distinct issue as it made further approach more challenging for later users but also led to greater confusion with on-going adaptations. Uncertainty in the relationship and reduced impact of adaptations, given the depth from the display and users changing their orientation, resulted in occupying a larger portion of the display through window and physical position.

While the increase in depth did limit the effectiveness of on-going adaptations, the increased awareness users would have towards one another, and the relative interactions between windows did lead to more localised interactions in trying to distribute windows and space more evenly. This was only limited by the action of individuals where there was no apparent need to adjust or interact with others. In particular, where users were near the edges of the display with a stable window they would occupy a significant amount of the screen. This would leave all others limited in their attempts to distribute themselves. This was a prime examples of where users should be actively adapted where these is an obvious wider issue.

User were generally happy to share the space and for adaptation to move windows as long as it was limited in how it impacted others and that the immediate reasons could be identified and would then cease. Where there were multiple adaptations or users were required to actively search for understanding this would begin to cause separation from the interaction and a distinct irritation with the system. Many of these points were thought to be time dependant, with a certain number of interruptions in a given time being acceptable, but with the pace of the trial making this difficult to assess. In many cases users did not notice the location of interactions across the display but the effects were felt due to propagation.

7.4.1.3 Critical aspects of the Targeted interactions

The initial entry behaviours were seen to be the same in both configurations, with the adaptation playing the same role in both. Users would select a gap – the left hand most in the distributed case - and approach, before the adaptation would either confirm the approach or draw attention to give a leading effect. This was expected in the distributed configuration, but was unexpected in the Clustered, where the Honey-Pot effect had caused on-going issues in the previous study. It was seen that an established tightknit organisation during entry was thought to be due to the system and acted to prevent new users from trying to join, instead approach was made either; towards the gap directly via interpretation of the space, otherwise the adaptation would be identified during entry and act to lead users, or with users approaching the edge of the cluster as a staging space to observe on-going content windows before adaptation would draw attention and gain the interaction.

A similar sense of system control was felt by those who identified the adaptation during early entry, but less so by those who saw it as a later confirmation, where it was felt the interaction was entirely user-led. The same was not thought by users in the distributed configuration, where decision making was based on the configuration and available space. The role of adaptation was limited in comparison due to reduced awareness of the display once a user had approached, yet still acted in the same manner to confirm and lead although only locally.

With this in mind, the second and third users entering the clustered case reported a lower influence by the system, with approximately half suggesting the system was creating space on the right and showing a window. The other half quickly identified the lone users and obvious locations to interact before approaching and later seeing a window. Of all users entering second and third there were no further instances of clustering outside of glance behaviour which was quickly supported with creation of a new window.

With the distributed case there was also a consistent secondary approach to the right end, although this could not be attributed to the system or adaptation. Instead there were seen to be more subtle influences of movement and organisation leading to the right hand gap being larger and drawing users in directly. With the third user, however, the approach was almost always attributed to either the gap at the display, or by adjustments in position of those at the centre indicating a gap being created. This type of physical feedback was a strong indicator that this was the correct position to approach.

The subtle physical movements of users in the distributed case were also present in window creation, with additional movements in to available gaps after an adaptation to create a more comfortable formation. This is likely related to the minimum $1/7^{th}$ or 0.35m separation being too low where there is additional space available. This movement was less pronounced at either end likely due to the edge of the display and wall, however, the result was the centre gap being reduced making the right gap appear larger. The result of these movements after the second user entered was for there to be a larger spread of windows at either end, requiring movement to create the third window. The result was for three windows to be more tightly bunched in the centre with areas with dead space between the windows towards the ends. This tendency to over-adjust in the early stages results in a reduction in usable space, and higher local densities leading to further adjustments and propagation.

Not accounting for the distribution of windows in the local area led to several issues. Where a window could be shown in the minimum gap this may leave users feeling overly close or compressed by those around them, and users were seen to stand back from the display instead of joining the line formed. One user in the clustered case reported directly that they felt they should have the same space available to the other windows shown and that it was unfair they had less space. The solution in both conditions was that users would use the window interaction to apply “pressure” on the adjacent, or offending window, to encourage negotiation in a similar manner seen in the responsive study. While adjustment worked exceptionally well, with on-going users quickly responding to the movements, users were wary of encroaching upon other windows and disturbing an interaction. This leads to considerations of whether adaptations should be carried out with a wider use case in mind.

A further, more subtle impact seen early in the distributed case was the movement of a position marker across the top of the display, causing slight following behaviour from on-going users. This point was not repeated but adds an interesting element of peripheral impact upon behaviour.

The use of the responsive state to organise the space was highly effective, with users identifying the interaction through the display to make adjustments, being happy to share the space as long as they had a window. Issues arose where interactions led to “flickering”, or rapid changes in the window display state. This was highly distracting across the width of the display and a strong argument for having wider reaching adaptations to consider how a new users may impact the local area. This was also echoed in the cluster where space was limited. User reported wanting to leave if they had not be placed there due to the window interactions. This suggests that where an adaptation takes place, it may be useful to adjust multiple windows to pre-empt knock on effects or remove dead space.

Interpretations of flickering proved interesting where users considered windows were about to merge where a new users had entered. In one case the windows was seen to be “juddering” suggesting the users should move back from the display to stabilise the window.

This interpretation of window feedback as a need for the individual user, and not related to interactions between users, conveys the importance of feedback and the relation to individual ownership, where the use of peripheral feedback may be more effective.

Expanding the role of feedback in the distributed case, which is far more dynamic, there was a significant issue with new windows being shown between on-going users but not being identified or approached. This caused on-going users to physically glance around to locate the new user and shifted the experience away from the digital awareness. This causes an issue for further layout changes may be missed. In this configuration the distances are limited, but the implications do require consideration, as several users reported the layout changing while they were not engaged and becoming lost or confused in the interaction.

This concept is expanded when considering the experiential elements of the trial, with users feeling "pushed aside" due to entry as feedback does not indicate why the adaptation is happening. Instead the adaptation becomes a social pressure instead of system-led, with users having to identify where new users were and what their personal impact might be due to approach and interaction. This proved mentally challenging and distinctly detracted from the experience in feeling they were required to move. While this was seen in the previous study, the inclusion of automated changes takes away the human nature of the interaction as the responsive nature of the windows is no longer apparent. This indicates that the nature of feedback and window creation should be carefully considered to address this issue.

As an additional pressure, the movement of windows along with a content timer and having to accommodate approach resulted in a need maintain the interaction and awareness. This led several users moving back from the display to maintain a sense of control. This breakdown in formation then leads to poor entry behaviour, with loose formation making awareness more challenging, coupled with the reduced impact of adaptation and adjustment where the user is removed from the display and can turn their head to follow any changes.

While these looser formations were better able to identify and account for one another when sharing the display locally, the wider impact was not identified. With individual behaviours significantly influencing wider organisation and individuals occupying large areas of the display, particularly at the edges, and not engaging with either feedback or the behaviours of the formation. This presents another strong indication that wider adaptation or adjustment should be applied in given situations to prevent localised issues arising across the display, and potentially preventing issues of retreat and organisation.

With all of these factors taking place, users were still happy to respond to adaptations and share the space, however, there were limitations on the number of times that users would accept layout changes as well as the level of impact upon others. This was related to both the amount of feedback and the awareness of others in the space after an adaptation. Multiple adaptations were also irritating, especially with the limited understanding of positions of new users. This could be solved by either putting time restrictions on the number of adaptations, or by applying wider ranging, or bulk adaptations and adjustments periodically to prevent the issues, as long as they conform to the above considerations.

7.4.1.4 Summary

As such, the application, effectiveness, and timing of the targeted adaptation can be considered;

- System led adaptation can influence how new users are likely to interpret the space, either through attractive or repulsive organisations, or the use of adaptation to draw attention and reinforce decision making.
- Highlighting interactivity around gaps can influence approach or draw attention in the local interaction.
- Assumed system-led organisations of users are seen as separate groups.
- Subtle factors of the environment and factors of display movement can have local influences where adaptations take place – this can be seen as small adjustments where users are already moving and so are susceptible to influence.
- Adaptation is a powerful mechanism to influence position of users but it should be incremental and not result in local social pressures where there is additional local space available.
- There are several cases for adjustment and distribution of users over the wider area around adaptations:
  - Presenting a window will not always encourage approach if the user feels they are not receiving a fair or sufficient space to engage. This is related to the local distribution of users and awareness of available space.
  - Individual behaviours and use of space can have knock on effects across the display and should be handled by adjustment to better support wider use.
  - Preventing multiple adjustments and impact to other users leads to an improved experience and can be handled by considering wider distribution for local results.
- Being moved for a new user without clear feedback or knowledge of their position changes the on-going use to a social issue, where the users is “pushed aside” by the approach and is concerned with their impact on the new user. This becomes “mentally challenging” and significantly reduces the experience and must be avoided through application and feedback.
- Feedback has multiple interpretations and affects used in a number of ways:
  - Flicker can be interpreted as merging windows or a need to retreat to regain control. There is no direct relationship to interaction between windows as the window may be thought to represent the individual.
  - Feedback can be used to encourage loose formations which are effective in addressing local organisation but at the cost of interaction and the effectiveness of further adaptations. This should be addressed as a series of design consideration.

With this in mind, targeted adaptation appears to be highly effective during early entry conditions, where the organisation of users can be carefully managed to best support the intended outcome. Limitations emerge where there is reduced space or awareness at the display and feedback to new users is limited in drawing them in. When new users are at the display there are additional considerations of how the adaptation is presented and the wider impact of distribution which may influence engagement that should be carefully considered.

There are also significant impacts upon on-going users, especially towards the experience of the wider space, where adaptation influences position across the width of the display, either directly or through more subtle adjustments. Limitations in feedback and the general understanding of the social pressures due to approaching users can have serious impact upon the experience and the effectiveness of adaptation. As the use of the space changes the role and application of this strategy should be adjusted to consider how wider distributions, or bulk adaptations and adjustments can be used to better organise the space. This works to both highlight positions of interaction and the behaviour of the display, as well as supporting on-going users in their interpretations of the experience.

7.4.2 Response to the Constant adaptation

The constant adaptation tested two factors; firstly, how do large movements of on-going users influence entry and awareness, and secondly, how do large adaptation affect on-going user experience. The interactions seen in both configurations are now described below.

7.4.2.1 Clustered - Continuous

In every instance of entry the first new users would approach the right hand end and the large gap shown there. This proved a significant yet enlightening problem to the interaction. Most all users entering the space identified a change to layout and related this to their entry;

> "The instinct is to approach the gap … the adaptation is linked to my entry and I felt very bad for influencing everybody else - it wasn't related to my actions or movements but was only due to me entering the space … it was very bad to influence so many people"

> "It seemed random, but I didn't care … something was just happening – I wasn't bothered about the people in the space, I just wanted a window - there was lots of movement and it was distracting, I couldn't find my window with all the movement."

These conflicting viewpoints encapsulate the general consensus of users entering the space, with many being highly aware of both their actions and impact upon others, but equally, there are many who are comfortable to make a decision and stick with it. In the latter case, the users indicate that once a decision is made they pay little attention to the display, but instead react to the behaviours of those in the space until they can achieve a window.

This raises an interesting point for the study design. As this interaction was seen second there is a concern that users may be pre-conditioned to approaching the gap, and so their response not being valid. However, the distribution of responses suggests that novice users are not initially fixed in their decision when the adaptation takes place and instead accept that this is a new form of interaction.

The main factor for on-going users was the surprise and speed of the adaptation. As there was no indication of the change or entry of a new user, the immediate movement of all windows resulted in confusion and glance behaviour within the group, indicating consensus before a decision was made. This did not ensure movement as local factors would influence decision making; a delayed response from those on the right and the tight-knit formation of the cluster prevented those to the left moving, this prevented new user gaining awareness of the adapted window resulting in continued approach the right end. After approach the user would interact with multiple windows preventing further movement from the on-going group. The new window created on the left would act to capture the left most on-going users who believed the window to be a correcting factor, those moving to the right would find the new user engaging with their content windows (identified by the colour of the position marker) and would look across or attempt to share (Figure 7-3).

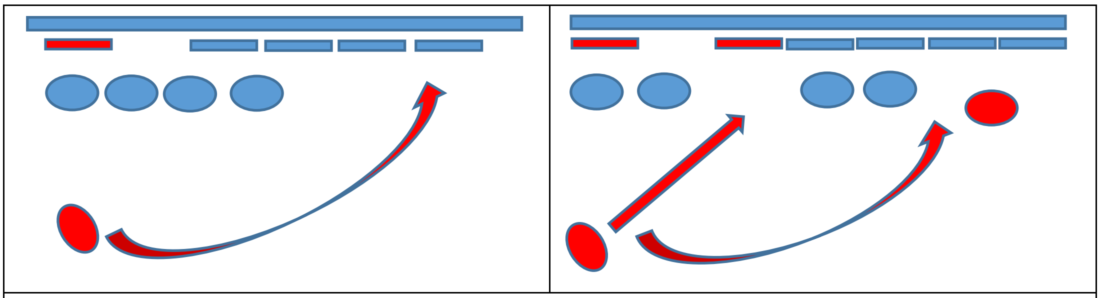


Figure 7-3: Showing first and second user entry in to the formation after Continuous adaptation in the Clustered condition.

The result was the group being split, with significant uncertainty in where to be and which window's to interact with, and the left most users being anchored to the left edge. The significant scale and speed of the movement took many unawares, with the presence of the new window and new user making correcting actions difficult. As on-going users attempted to interpret and correct the second new user would be entering and approaching the right hand end, avoiding the on-going group distributed across the left side of the display and approaching the wider space and windows shown to the right.

From the point of view of the on-going users to the right they were still sure that the windows were theirs, however, once there was somebody in that position there was a strong resistance to move over and engage as this would interrupt their experience. Instead, the majority of users without windows would attempt to identify another window with the same colour, or specifically seek out the same article of content, although both were reported to be poor substitutes. The use of colour was particularly pronounced during the adaptation as windows moved away the users who reported noticing their particular colour more vividly in comparison to the other windows. This was later used in recovery.

While continued adaptations did cause movement of the initial formation towards the right, with some further movement to the right with time, this had the effect of drawing the formation out and many members stepping back from the display to try and identify tracking in the windows which were shown. There was also a secondary issue of where to interact within this formation, with new users adopting windows to the right and the on-going group forming and negotiating for position around the windows available in the centre, which the left most on-going users felt a claim towards given prior ownership.

While there were high levels of confusion in early entry and poor formations of users, with later entrants the on-going formation began to stabilize and as a result there was a higher level of awareness towards the display. With several new users following the distributed "largest gap" approach, either immediately approaching an available gap, or assessing the space and looking for "stable" windows found on the right hand end. Although, a portion of later entrants were seen to achieve the responsive state and a full window within a short time of entry based on the current formation allowing access to the landing area.

The major on-going issue being additional adaptations with users having very little understanding of the meaning. These continued adaptations, while supporting new users had the impact of slowly bunching the on-going users to the right with each change. While this was more pronounced with each adaptation, there were issues for those at the display.

The continued bunching had two effects on use, with multiple users continuing to engage with their window and identifying that:

> "Personal space was less important, as long as I could have my window and it was clear, I didn't mind moving up to others … as long as there was a display there, most of the time it didn't matter where people were."

In several cases, however, users would become disillusioned with the adaptations and lack of any immediate response, with no indication of tracking being the main priority for most users. Many indicated they investigated the system and multiple windows searching for tracking to confirm they had a window, with the concept of ownership of a single window being in high regard. Most could see others had windows but they did not. In actuality most users were standing at the window of their choice with no responsive behaviour shown.

In search behaviour by on-going users', windows shown in large gaps but with no obvious user were ignored due to these windows considered to be in use. This made exploration and understanding much harder in these cases. With continued adaptation both new and on-going users identified the left hand end as a free space as more likely to contain a responsive window. As the adaptations continued small clusters would emerge at the left end taking turns to achieve a new responsive window before an adaptation would move it to the right and allow the next approach. This was seen in half of the cases, where the initial on-going response had been to stand still, ultimately leading to wider confusion between all users and so greater awareness of new windows forming.

The most telling aspects of adaptation were the experience and expectations of users to these changes. Where the previous trials had generally supported local decision making there was a strong backlash against the greater impact of the system:

> "It is not nice to be controlled by the system … small corrections are fine but not moving across the entire space … it could be psychologically unsettling"

User were quickly confused by what the adaptation was attempting to achieve with such large, quick changes to the layout with limited feedback. While many were able to infer there were new users entering the space and that the system was trying to re-arrange users, this broke down where the responses of others did not match the expectations of users;

> "Movement completely broke my expectations of the system so I just ignored it"

> "It is not users centred … it should respond to the user not to the space"

> "The system should not respond so much to other people in the space – having to move so much is going to lead to a bad time"

This had an extremely negative impact to those already at the display when considering new users, with most indicating they did not mind changes before now as these users were in the background. Instead, new users were blamed directly for the annoyance, with many new users also feeling directly responsible for impacting the on-going experience.

> "It is annoying that other people come in and can control me – before it was fine because they were in the background - it could be fun if it was just me, like the system was playing with me"

> "Identified that new users were in the space – annoying and blamed them for causing the change"

Where users could not follow the adaptation or were prevented from being able to get their window back due to new users in the way, the significant issue was in the lack of responsive feedback in identifying points of interaction. While this was a design component of adaptation, with windows being fixed after the adaptation, it ultimately resulted in most users not being able to identify a window for themselves. This exacerbated the issues of movement as multiple users would search the area for interactivity and so limit the effectiveness of the adaptation in organisation.

While there were indications that the adaptation would encourage movement, the speed and timing of the changes were the critical issues in facilitating this and most users requested that additional feedback would be greatly beneficial. This considered both earlier warning of the movement as well as "non-linear" movement speeds to allow for interpretation and response. With this in mind, the overall intent of the adaptation after the fact was seen to be a negative factors of this trial, with many users not wanting to move significantly through the space and the need to traverse the width of the display seeming like a controlling factor of interaction. Particularly when there were multiple movements of windows and no immediate feedback on where new users were. This was considered socially challenging as large movements could cause a direct impact upon a new user attempting to engage.

7.4.2.2 Distributed – Continuous

During entry the first users were seen to move in to the centre of the space and towards either the centre or right hand end of the formation. As the adaptation is triggered the on-going users were initially slow to react, leaving the new users to either, achieve a responsive window at the edge of the landing area and change their approach to this location, or to continue moving right and slot in to the formation while the adaptation was still on-going. With the slow on-going user response the new users were free to investigate their window, before the adaptation fixed their window in to the layout.

With the slow response there were several behaviours identified in the on-going group, with some members responding relatively quickly, and several members of the formation glancing between one another to identify if there was going to be a shift in position. In cases where there was movement from the right of the formation the remainder would be quick to respond and move towards the right hand end, however, there were again issues of the left hand users being less inclined to move, or anchored to the edge (Figure 7-4).

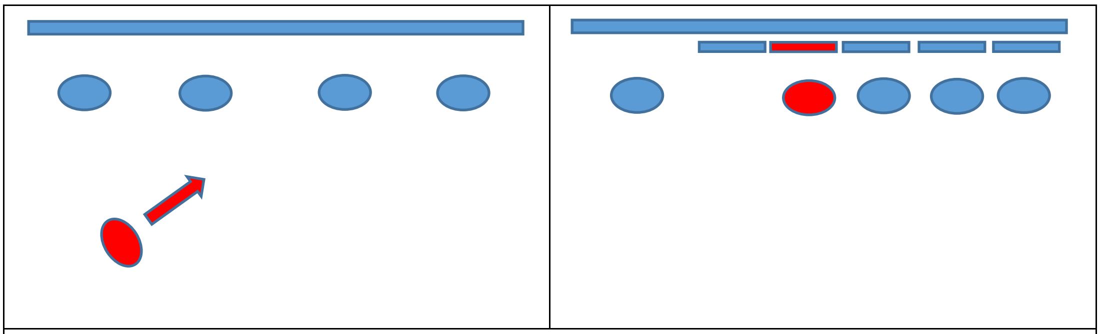


Figure 7-4: Showing the new user locked in to the layout after the Continuous adaptation in the Distributed condition.

The issue of group movement was somewhat limited with the single new users having entered the space and gaining a window in the formation, as there were several users who could no longer identify where this person was standing and how the movement of the windows may relate to their position. This led to physical glance behaviour before responding, instead of directly following the moving windows. This change in behaviour from the previous trial across the formation was interesting to note, with several users reporting an altered interpretation of the space and the desire to move;

> "…previous time it was the whole display we had to move across – this time may have been the same distance but it felt a lot less, it was just a part of the display. Last time I was aware there was a lot of space to cover, but now we were more spread out and were all moving together which felt better."
>
> "It didn't seem too fast this time maybe because it wasn't so far."

The distribution of users made interpretation far easier and reduced barrier to adjusting position, particularly where other on-going users were seen to respond, however, there were still issues of single users not responding holding back those to their left.

While those on the left indicated they may not want to move, either due to adaptation or distance, there were also considerations of how the first new users had entered the space and the impact this had to the groups' initial organisation and positions at the right hand end. This was further compounded by additional new users interacting around the left hand end, suggesting that remaining still may be a simpler solution;

> "There's a kind of inertia to not move once you have a space."
>
> "When the window moved I checked I wouldn't annoy anybody but it was fine, there was no one behind me so I moved."

For those to the centre and right of the display the sense of the adaptation seemed to be a "pushing" force as new users entered. With their being no feedback as to their movement or position, the knowledge of a person entering and the adaptation suggested being shuffled or moved out of the way, although this was not seen as negative per se. While the majority of on-going users were ultimately seen to move with the adaptation, the users remaining on the left end had a significant impact upon the entry of the second and third new users.

With the first adaptation there was a general movement to the right, with cases of the user second to the left moving past those in the centre to follow the adaptation. Issues arose where a single on-going user would remain in the landing zone and become distracted by the responsive window as additional new users entered the space. This was particularly pronounced where there were two on-going users remaining on the left hand end, leaving large gaps to the right. Where these gaps existed the obvious approach behaviour for new users was to move right, resulting in a loss of the responsive window and approaching the available gap. This made further adaptation very difficult to interpret for those in the space and resulted in an extremely poor experience as windows moved away (Figure 7-5).

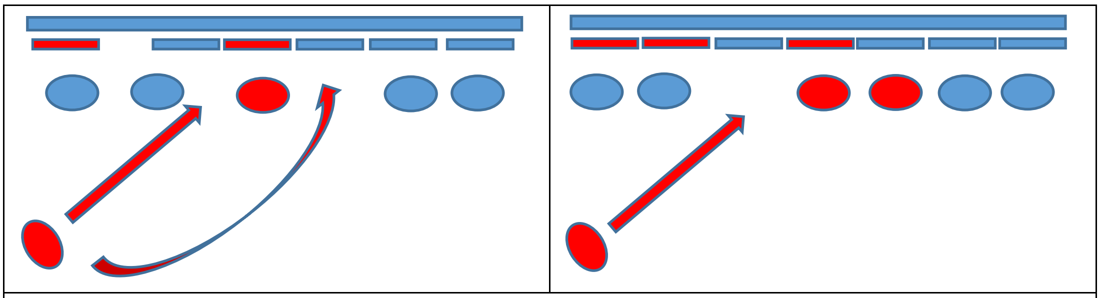


Figure 7-5: Showing second and third user entry in to the formation after Continuous adaptation in the Distributed condition.

Where there was a single on-going user it would generally be the case there was sufficient space for new users to identify tracking and responsive windows on the left and quickly approach this area. This would result in negotiation but would generally be resolved with the following adaptation moving both windows and providing a defined space for each. The major issue with the single on-going user on the left was the uncertainty of where new windows might form in relation to them and a lack of interest in moving, so leaving the user isolated from the group and their initial content. This would tend to lead to this person moving back from the screen slightly and observing several windows, or attempting to interact with new windows forming. This further impacted on the ability for new users to identify and engage with their window, although generally this was resolved quickly.

With both scenarios of new user approach, the second and third adaptations would see a significant clustering of users on the right hand end, with each person clearly interacting with a single window. While the windows were fixed in position as part of the trial design, this raised few issues, with several suggesting that the responsive mapping could have been beneficial, but the major consideration being the stable nature of the windows and predictability of adaptations. While there were problems with the positioning on the left hand end, the interpretation during later entry was generally good as it was seen as the only available space. Further, windows generated here were quickly identified as new and separate and so approach was possible, but also followed during adaptation.

> "When I came in I saw everything move to the right, that was important … I was able to find a place … I assumed everyone would move with their content."

This sentiment was generally held by all of those at the display, with many suggesting this approach was far easier as the movement to the right was easy to interpret upon entry as the majority of users were following the adaptation;

> "It was very easy to just move to the right – it didn't take much figuring out."

> "People seemed more physically fluid, there was little problem being able to move."

The major issue in the interpretation was with the initial response from the on-going group, where many members would look around for a cue or indication from the remainder of the group. The physical separation did a lot to alleviate the concept of group consensus, as individuals could respond freely and this would further encourage movement. Even then, the actions of a single person could prolong or completely prevent the group moving with the adaptation, and so users would lose their windows as they were piggy-backed by new users.

> "The windows moved but no one else did so I stayed still – I was thinking of moving but then people slotted in and I couldn't get my window."

> "If people had started moving right we would have all moved and it would have been a lot better – because we didn't move it made it a lot harder – there was a knock on effect of people not moving."

> "Then there were other people in the space and I didn't think there was enough room – I wanted my window but it was already gone – I just found something else."

While these factors proved to limit the immediate effectiveness of the trial, there were several comments related to this experience that may support further development.

7.4.2.3 Critical aspects of the Constant interactions

The initial entry behaviour highlighted several components of the adaptation. With the Clustered configuration the first new users was seen to aim directly for the gap, as had been seen in the previous trial. With the Distributed configuration, however, the triggering of the adaptation during entry appeared to have a significant effect on decision making, with almost all initial users entering the space moving in to the centre and right hand ends with the adaptation. This was seen to be due to the movement of the windows and on-going users during entry, making the left and centre portions of the display unstable and ineffective as approach and interaction points, while the right hand end presented gaps and free windows.

The response behaviour of on-going users to this adaptation between the two configurations saw clustered users being extremely limited in their responses due to the distance and speed of the adaptation. There was significant glance behaviour within the group in efforts to form a consensus, and a resistance to move unless there was an initial response, usually from the right hand end. Considerations of the Cluster density and group consensus appeared to play a large role in this decision. The Distributed case prove to be far more engaging for users as the perceived distances and speed of window movement was lower given the starting positions. This resulted in a greater response rate from on-going users and in the majority of cases led to almost complete movement and grouping of these users, along with reports of a positive experience. The extent of this being a learned effect may have been addressed in a further focussed round of testing.

Between both cases there was still an issue of new user slotting in to the formation due to the slow response and a large gap in the formation on the right hand end showing stable windows. This would influence how and where new users would be able to approach, with many identifying the gap and stable windows on the right as their first choice. The timing of the adaptation proved challenging for the first new user, as it was felt the adaptation of windows was directly related to their entry and the change caused significant issues for those already in the space. This ultimately had a psychological effect of remaining fixed to the initial approach position to prevent further adaptations or movement in the layout.

In both conditions, the edge effects around the formation proved to be a deciding factor in the response, with new user approach to the right, separating ownership and subsequent following behaviour for those already in the space. With both cases, the leftmost on-going user, while separated from their window, would be presented with a new window in the responsive state which was reacting to the new entry. This would act to draw both attention and interaction from the left most, and in the case of the clustered condition, several users at the left edge, back towards the free space and "landing zone". Ultimately this would lead to a clear separation between the on-going users, with several responding to changes in layout and the remainder holding position.

The significant issue between the two conditions was seen to be the rate of response, or reorganisation of the formation of use, with the clustered case leaving a significant gap on the right containing several stable windows. The initial entry in this condition led to multiple new users moving to the right, both with and without awareness of the interaction shown in the landing zone. The distributed case offered a greater opportunity to interact with the system upon entry, but the presence of fixed on-going user to the left led to clear separation and uncertainty in the interpretation. This was mainly countered by the presence of the responsive position marker and gaps shown on the left hand end.

The isolation of users on the left edge led to several issues with further interaction, where on-going use prevented direct approach given the available space, but also acted to produce a buffer to approaching the display during direct interaction with a window. In particular, the Clustered case saw several on-going users remaining in the landing area, so preventing interaction and approach and finally leading to new users approaching the right hand end. The Distributed case saw more availability in the landing zone but did not fully accommodate entry or approach. In particular, the confusion of the adaptation resulted in movement back from the display while trying to re-capture interaction with a window, which led to a significant separation of new users to responsive windows and engagement.

Successive adaptation were seen to significantly impact the organisation of use with a general movement to the right creating a landing zone on the left. This was more pronounced in the Distributed case as users were more willing to follow the adaptation given the perception of reduced changes to the layout, however, it was also the case that the Clustered configuration saw multiple new users approaching the right end given the early organisation. This effect was particularly prominent in the Clustered case, where gaps showing stable windows on the right drew the majority of new users, and interactivity on the left missed.

The interactions of users on the right hand end had a mixed response, with multiple users attempting to engage in the Clustered case, findings issue with the lack of interactivity and failing to identify ownership amongst the windows shown. In the Distributed case, users were far happier to interact, as long as they felt they had an individual window and were less concerned with sharing the space. This may be linked to the general movement allowing re-capture of a starting window, and the reduced number of new users interacting at that end. This ultimately led to multiple users searching for interactivity, and identifying a desire for a single window regardless of the nature of behaviour around them.

With additional entries, the organisation of users had two distinct outcomes, with the right hand gap in the Clustered case presenting resistance to searching and recovery behaviour as windows were felt to be occupied given that they were shown on the display, this could be considered as a sub-set of the "digital awareness" of the user-display interaction. This gave rise to on-going users avoiding the gap in favour of the landing zone, where there was a greater understanding of space and interactivity, leading to turn-taking and a cycling effect around the point of interaction. Conversely, the lack of gaps due to use in the Distributed case gave a sense of a "pushing force", as each window was occupied and moved to the right with each new entrant, so creating space for new users and being easily open to interpretation for those being adjusted.

The interpretation of both conditions was seen to be linked directly to the initial response of the on-going users. In the Clustered case there was a very quick separation from the meaning of the adaptations and future interactions with content, compared with a reported "flow", or predictability of users through the space in the Distributed condition given reduced barriers to interpretation. While both groups suggested that the group decision, supported by an initial reaction from the right most members may aid in the decision, the barriers to movement were far more significant in the Clustered case. While the distances travelled in both were approximately equal, the Distributed condition seemed to offer a significant reduction in the required movement to all on-going users.

The significant issue in the Clustered condition appears to be around the lack of feedback related to the distance needing to be travelled. The initial interpretation is of new users entering, resulting in distraction, and the content moving significantly without clear relation to why given their position in the space and lack of new "responsive" content shown. This is further compounded by a bulk movement of windows, instead of piecemeal or localised changes which may or may not be followed, leading to social and physical barriers of other users when attempting to follow the changes. In addition, the physical layout of the screen offers anchoring positions that are easily interpreted and in many cases this behaviours is an active decision, so proving difficult to address via direct adaptation.

An overarching factor within this trial was the lack of interactivity, or "responsive state", of windows. This was seen in both searching behaviour as well as stable interactions after adaptations. Where searching the display users were seeking to identify a "tracked" or interactive window to establish a point of interaction, whereas in the stable cases the onus was on adjustment between users. In both situations the significant factor was the perceived ownership of the window and control over the interaction and local space. While many users did not mind sharing, the concept of direct ownership was pivotal within the experience as it separated the interaction from a highly negative interpretation of the overarching system-led response. While there were several interpretations of the system leading and supporting users in a general movement or flow pattern, the lack of any form of control after the adaptation left users feeling isolated and uncertain about their actions.

Suggestions around the adaptation pointed to a staggered, or staged interpretation of the necessary adjustments, with slower movement speeds of windows and additional feedback to support decision making. This could be further supported by physical movement in the space with the right most users being adapted first to encourage or suggest the response. This, coupled with consideration of where adaptations were applied across the display related to when and where new users entered, offers an opportunity for more effective management of the space, with significant improvement to user experience.

7.4.2.4 Summary

- New users adjust their approach with the movement or flow in the space, but also respond to the final organisation, such as gaps and the position of other users.
- Early response to adaptation encourages movement of on-going users but is tightly linked with the formation and timing of the changes, as well as edge condition.
- The requirement for on-going users to adjust can be related to physical parameters of the space, but can also be drawn between the behaviours of one another, with glance behaviour and early movement shown to influence later actions.

- Timing of the adaptation may encourage movement behaviours, but could also help with interpretation and identify landing zones at the display.
    - Where new users were presented with a late response there were significant gaps and separation of on-going users from their windows, leading to approach towards gaps with windows shown.
    - Later entrants were offered a richer interpretation of the space as adaptation only took place in the landing zone, drawing attention, allowing for interpretation and discovery of interactivity.
    - Timing of the adaptation may directly influence the interpretation and could act as a pre-emptive change to better support the space.
- The edges of formations act to define the on-going use of space – where there are edges there are anchoring effects and speedbumps to changes in behaviour based on the group consensus. Clusters do not respond well to bulk changes, but may respond to progressive local edge changes.
- While adaptation can free up the landing zone, the position within the space significantly impacts approach. This does not limit response to adaptation, but presents a confounding issues between several users and blocks new entry.
- With feedback and awareness of the adaptation on-going users are more likely to respond in kind, ultimately leading to an informed entry for new users triggering the changes. This is more pronounced where adaptation can be interpreted or understood by the on-going users.
    - Successive adaptations lead to a Clustering effect in the direction of change highlights the landing zone as distinctly separate as was indicated in the Clustered - Targeted.
- The distributed case is more compliant to the adaptation given a “pushing force” collecting users together. The Clustered case sees users moved out of the way, which does not make sense in terms of the interaction, but could be a valuable mechanism.
- It is important to remove ambiguity from the space before new users are able to enter and position themselves without requiring correction. A lack of response to adaptation during entry re-orientates the adaptation to a leading effect for the user.
- Responsive windows play a large role in how users achieve a stable interaction. Where there is confusion there needs to be a factor of immediate feedback. This is reduced where an initial interpretation has been made, but offers potential in preventing confusion and movement in the space post adaptation.
- Where incremental changes to the layout might support response to adaptation given configuration, this must account for new users entering in achieving a window.
    - New user will require time to interact and establish ownership. Continued adaptation of surrounding windows or a new window may separate this prematurely.
- The constant adaptation is more effective once on-going users are aware of the interaction and new users are able to interpret the meaning of the change.

Considering these factors, the continuous use of adaptation appears to be most effective as the interpretation and response becomes better understood. In this case it is seen with each additional entry offering the chance for interpretation and a general movement pattern being established. The onset of this movement pattern is seen to be closely linked to the initial response of on-going users, with factors of window movement speed and distance influencing the interpretation. This is alleviated in the distributed condition where the distances and apparent movement speed appear reduced, as well as leading effects between users, particularly to the right of the formation. This acts to encourage a response from the group, although approach to the right by new users still has a significant impact.

The limitations in initial interpretation of the adaptation and factors in the physical space point towards a two part approach in the use of this adaptation, where; components of the physical space which offer situated interaction should be maintained, i.e. edges and clusters of users, and the timing of adaptations during entry should best support new user entry to describe the nature of the space, but also to provide landing zones in front of the approach direction. With this in mind, relative changes to the layout, namely chances to interpret feedback, should be on-going for this adaptation to be most effective. At the same time any movement should be aiming to situate users in static positions at the extremes of the display where interactivity and ownership can be established and maintained. This ensures landing zones can be quickly cleared, with allowances for edge effects, but also promoted understanding and effective response behaviour where required, so managing later approach and reducing issues of exploration while searching for points of interaction.

7.5 Considerations of adaptation relative to entry and on-going use

Decision making in entry has now been shown to have several links to both direct and indirect factors of adaptation. Where static organisations of users can define where there are points of interaction available, such as clusters and gaps, movement can be equally as effective in influencing entry and approach.

Of the two adaptation strategies it is evident that both can lead to varying forms of organisation in the space, as well as presenting movement during entry. Where continuous adaptation can lead users to form clusters, either in the initial organisation or through on-going changes, this results in altering the configuration of use to create both gaps and clear landing zones, as well as implying the nature of movement in the space. In comparison, targeted adaptation offers more immediate feedback in drawing and informing decision making and acts through both display changes and local influence to on-going use.

As both strategies influence the space in different ways during early use it is important to consider how any changes will affect organisation and how this in turn influence the effectiveness of further adaptations. Continuous changes rely on response to window movement and are highly susceptible to confusion in initial re-organisation. The distance and movement of multiple windows must be carefully managed and related to the timing of entry to ensure effective use and interpretation by all users. Targeted adaptation on the other hand is mainly effective where there is space for new users to identify layout or organisational changes, and so these spaces must be available as the space is filled. This approach suffers where the display becomes full or lacks clear organisation.

With the effectiveness of both strategies being related to the response of users at the display there are local issues that must be addressed to ensure that layout changes will be effective. The significant draw back in an on-going interpretation is that the majority of on-going users must be exposed to adaptation and respond in time for landing zones and flow patterns to be apparent. Where there are points of rigidity, such as edges or a lack of response, this quickly breaks-down as adaptation is ineffective and the use of space open to interpretation. Through factors of ownership and feedback and respecting social conventions supports a connection between users and window for adaptation to remain effective.

Fundamentally the use of adaptation is tied to the on-going use and engagement with the display, but also to the aim of the use of space. While adaptations can immediately influence the use of space, it must do so in a way that meets the expectations and requirements of those interacting so that others may clearly interpret and respond as intended. It therefore follows that adaptation should be applied in a timely manner to initially draw interaction and organise the space to best support new use and further adaptation. This includes the use of targeted adaptation to draw interest and ownership, as well as continuous changes to organise the space. This both offers new points of interaction but prevents later issues of multiple adaptation and poor use of space. In turn, these changes can be linked to new user entry to account for edge effects and movement patterns, but also allowing on-going users the best possible experience to support further adaptation.

It follows that for the optimum use of the display there are factors of both supporting on-going use to ensure effective response from those experiencing adaptation, but also that an overarching use case for the space must be presented to approaching users. By ensuring that use of the system can be supported throughout all phases of engagement, it is then possible for further changes to be made in a manner that perpetuates the status-quo.

7.6 Summary

This chapter has now presented ways in which adaptation can both encourage awareness and approach during entry through factors of awareness and organisation. Where both strategies are effective in offering localised engagement through direct feedback and increased awareness, there is a strong case for both being applied in conjunction to best support approach, as well as on-going use given the nature of interactions taking place and the continued effectiveness of the strategies themselves. Within this, any changes to the display layout must consider how individual users are currently engaging with content windows and the likely outcomes of the applied strategy to wider display use and new user approach. Through both localised and continuous changes, the configuration of users can encourage approach and understanding as well as supporting effective use of further adaptations. This now leads to considerations of how adaptations can be handled in an informed manner during entry relative to a considerations of on-going use.

7.7 Contribution to Knowledge

This study has now addressed the first three sub-question of question three;

3) Ground the role of system led adaptation within a framework for prediction and modelling.
    a. How are natural formations of users and user decision making related to system led adaptation approaches?
    b. What are the leading factors in user decision making when considering display feedback, social interaction or adaptation?
    c. How and when are adaptation strategies appropriate, based on user experience?

Building upon the findings of Study 2 - Responsive System, a series of the most significant factors of both display and users behaviour were identified and formed in to a series of simplifications around the natural use cases. This considered both the natural formations during use as well as learned behaviours that were seen to influence the nature of display interactions. These simplifications were then used to derive an informed set of adaptations to relate natural configurations of use to forms of approach of new users.

These adaptation strategies were used to develop the required changes to the supporting software and an investigation was formed around the manner of interpretation of approaching new “novice” users entering the space, compared with the impact upon the on-going user experience of those already at the display. This investigation identified the role and impact of adaptation relative to natural approach behaviour to the natural configurations of users in the space to establish their effectiveness and appropriate use across a variety of use cases and contexts. This understanding was then further expanded by relating the user experience of those at the display to these use cases, helping to better understand the impact of adaptation and further avenues of application.

This work has now shown the role of adaptation during both approach and on-going interaction behaviour and experience. This understanding now allows for an informed model of the wider use of space as well as specific factors of individual interactions, and presents a clear foundation for when and where adaptations should be applied across a display while in use in supporting both the approach and engagement behaviour of new users, but also to best support the on-going interaction and experience of those already at the display.

This investigation has now described how the findings of sub-question 2 have been related to an informed design and investigation process to answer the first component of sub-question 3 and to begin to explore the potential understanding of the final two sub-questions. These questions have themselves been answered and offer further insight and understanding of these systems to begin to further investigate the final problem space presented by the final two components of sub-question 3. This will now be laid out in the following chapter.

Where previously phenomena have been identified in this study there are now several clear relationships between adaptation strategies which had not been considered. These have been seen to not only influence behaviours at the display, but to impact upon decision making during entry and approach to influence the overall use of the display. This study has also presented the relationship of adaptation to user experience, such that the use of adaptation can be informed at an individual experiential level, as well as related to the overall physical impact. The relative impact of adaptation on the physical use of space now leads us to the final investigation of MISU interaction concerning modelling and prediction of behaviour relative to display use and configuration.

Chapter 8: Study 4 - Predictive system

This chapter now addresses the final iteration of system-led adaptations relative to entry and approach given on-going configurations of use. Drawing together findings from the previous chapters, feedback will be applied to support expected entry behaviour relative to the on-going configurations, and be evaluated in its ability to support approach and repair breakdown in interpretations by users towards delayed adaptations. The study will aim to identify a distribution of use cases and key factors in both system and user behaviours which support and conflict with expected interactions, highlighting critical areas of interest and further investigation around these types of systems.

The study will consider a predicted landing position identified during entry relative to the findings around approach given on-going configuration. The adaptation will not be shown immediately, with initially responsive and then leading feedback given via a position marker to support the users' entry and approach, with the adaptation being shown as the marker arrives at the predicted position. This will assess how feedback can support approach without the need for immediate adaptations, as this does not guarantee approach and interrupts on-going use. This will allow for the investigation of simple prediction and supportive feedback as a mechanism to better manage the use of space while mitigating impact to on-going use, and ensuring a correct decision has been made to identify any need for repair.

This will evaluate the minimum requirements for feedback in supporting approach without the need for adaptations as a direct mechanism, so expanding the potential effective range of support and spatial management beyond the room scale interactions which have been seen so far, towards an aspect of adaptive architecture.

This is presented in two stages; firstly, considering the previous findings leading to the design and implementation of the system along with the investigation approach, and secondly, the results of the investigation in considering the range of interaction Behaviours and influence of the system and user decision making.

The previous studies have identified the impact of adaptation in both user approach and on-going user experience. This has indicated effective applications of adaptation to best support approaching users while limiting the negative influence to on-going interaction. By considering these factors in combination, a set of approach-adaptation mappings are considered to assess how they support approach and recovery relative to configuration. These areas will now be considered.

8.1 System Requirements and Development

This section describes the underlying understanding found from the previous trials, along with aspects of the system which were implemented to support the investigation. This considers the steps taken in predicting approach behaviour towards the configuration and the applied adaptations.

8.1.1 Developing the Prediction Model

As discussed in the initial system design (Chapter 6: Study 2 - Responsive System), Modelling and Simulation approaches were used to generate agent objects of each users. These agents contained internal values to describe their position and movement behaviour, as well as interaction and world states, such that the behaviours of all users could be compared.

As an extension of these values a linear interpolation model was developed to predict the approach direction of the user towards the display upon entry. This was achieved by extending the tracking area beyond the entry position to ensure a positive tracking and accurate representation of approach direction at the time of entry. A threshold around the entry position was included to allow for changes in direction and behaviour to be accurately captured before a prediction was made. This can be seen in the below (Figure 8-1);

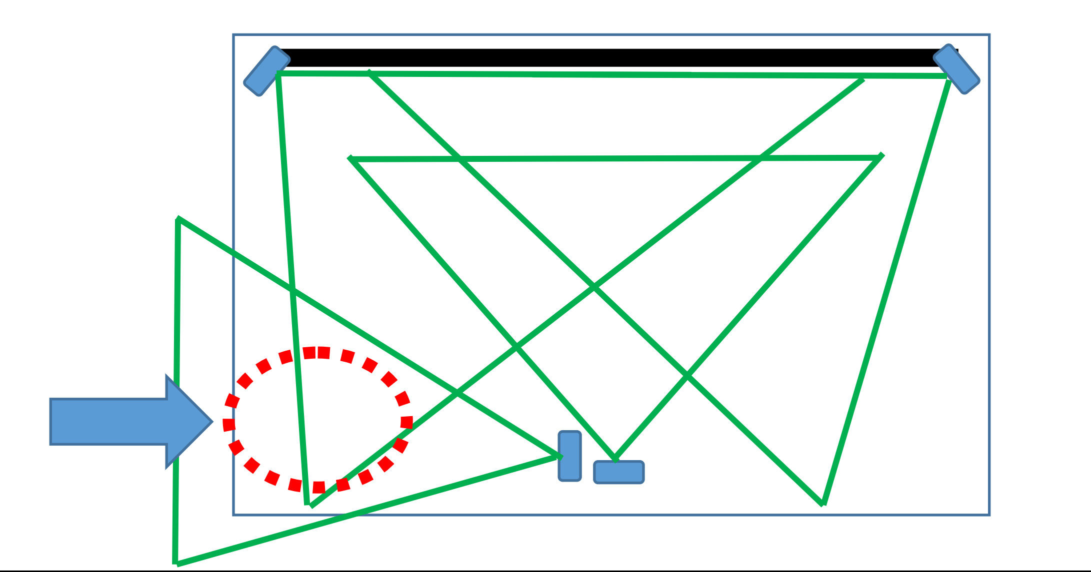


Figure 8-1: Showing the top view of the extended tracking area and approximate view frames (green) of all cameras, as well as the location of the entry threshold (red).

The approximate view frames of all cameras are shown in green, with the entry threshold location shown with a dashed red line. The new camera, #4, is shown facing the parallel entry location, with the tracking area extending approximately 1.5-2m beyond the entry. As described in the initial development of the system, the camera was included within the elastic array by defining the client ID, and location and rotation of the camera. The remainder of the system design handled unique ID's and tracking, leading to content window display.

By extending the tracking area the entry direction of participants was mapped to account for any changes in directions upon viewing the display and formation. As participant crossed the entry threshold a linear interpolation of changes in direction was made relative to the current formation. This was done in direct relation to gaps available to identify the most likely approach position and appropriate adaptation strategy.

Based on the findings of the previous chapters there were several available strategies dependant on the configuration of on-going use. These include;

The three adaptation approaches in the Clustered condition (Figure 8-2):

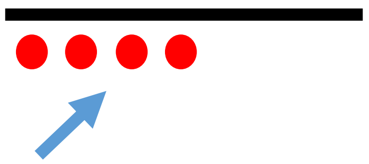
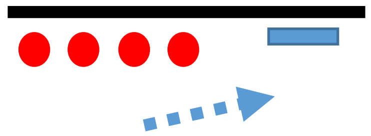
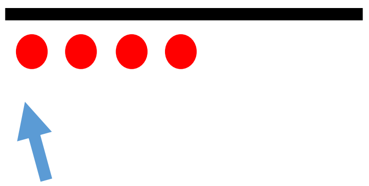
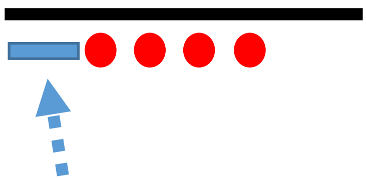
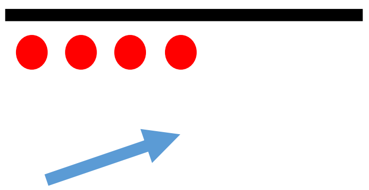
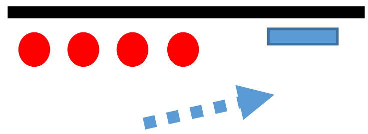
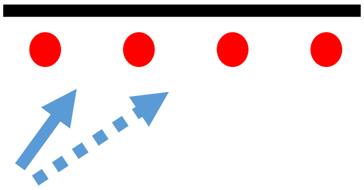
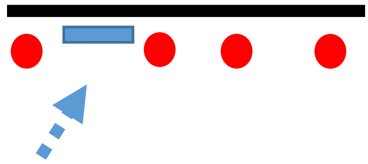
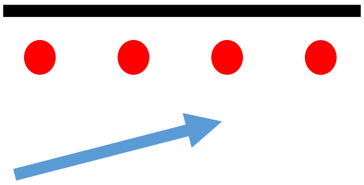
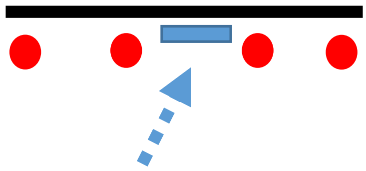
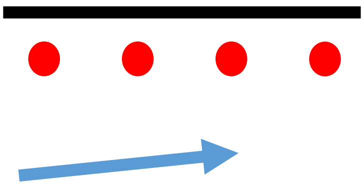
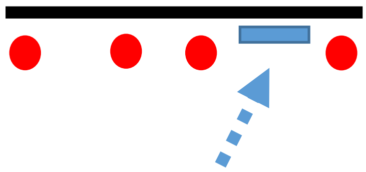
Formation and Approach	Adaptation and Optimal outcome
	
User is appraoching the rear or right hand side of the cluster	New window is created and moves to the right - user is able to identify and follow
	
User is approaching the left hand edge of the cluster	Cluster is moved to the right and the user is able to approach the new window
	
User is approaching the open area to the right of the display	A new window is shown and the user is free to engage

Figure 8-2: Showing the three adaptation strategies in the clustered coniditon.

Within these adaptations the ideal condition is to prevent the approaching user from impacting upon the on-going user experience by presenting feedback and encouraging movement. Feedback takes the form of a position marker shown at the top of the display. The marker remains "responsive" until the user passes the entry threshold and the approach position is set, with any movement of actors taking place if required to create sufficient space for the window. The marker then enters a "leading" state and moves to the predicted position shown and the window shown. The marker indicates the intended movement but does not indicate a relationship to the user or their actions outside of its movement.

In the Distributed case the adaptations are simplified due to the nature of the configuration. The system will attempt to predict the gap to which the user is aligned with the movement of the position marker to lead the user and present a targeted adaptation. The user is able to select any gap at the display to approach, as shown below (Figure 8-3);

<table>
<tr><th>Formation and Approach</th><th>Adaptation and Optimal outcome</th></tr>
<tr><td></td><td></td></tr>
<tr><td>The user enters the space and is able to approach any available gap approximately as far as the centre line of the display</td><td>As a gap is selected at the first gap and a targeted adaptation takes place and a new window is shown</td></tr>
<tr><td></td><td></td></tr>
<tr><td>If the users approach is beyond the central position there is less certainty in the target</td><td>A window is shown in the centre of the display before the user passes the position to drawn their attention</td></tr>
<tr><td></td><td></td></tr>
<tr><td>Where the approach is towards the extreme edge or parallel to the display there is ambiguity in the final position</td><td>Where the users position is still removed from the display a targeted adaptation takes place in the final gap</td></tr>
<tr><td colspan="2">Figure 8-3: Showing the three adaptation strategies in the distributed condition.</td></tr>
</table>

The position of users was found in the global reference frame to compare physical positions and available minimum gaps, identifying the configuration in real-time to establish a set of targets for approaching users. As the user entered the space and moves relative to these targets the final target is selected as the user passes the entry threshold.

These strategies present the least impact to on-going users but also act in-line with expected entry, although in was seen in the Adaptation Study that the initial entry may not represent the final engagement position. This allows for future work to consider how repair could be handled, however, this study will consider how feedback is identified and how it should be design to support users, allowing users to repair their approach based on the final layout. A step was taken to handle ambiguous entry towards the right hand end by placing the predicted position at the centre of the display in an attempt to lead the user. However, if the approach was extremely ambiguous, i.e. parallel to the display when passing the threshold, the furthest right-hand position was selected.

8.2 Design and Implementation of Study

As indicated in the above diagrams there are four on-going users in the space at the time of entry. These are actors who have previously been involved in the investigation and have been informed of the nature of the interaction taking place. The actors are familiar with the system responses and were asked to follow their designated windows no matter the adaptation or interactions with the study participant. This was done to promote a sense of realism to the study but also to evaluate the social interactions where the user was assuming control of their approach. The actors were also able to assist with the setup of each trial while interviews were taking place to ensure a smooth transition between both trials.

8.2.1 Study Design

There were 46 participants who interacted with the system, with 23 novice and 23 repeat users. Repeat users were those who had taken part in the adaptation trial and were familiar with the potential configurations and adaptations. Participants were required to interact with both configurations in a between and within study, such that half of the group would experience Clustered followed by Distributed and vice-versa, as shown below (Table 8-1);

	Novice		**Repeat**	
Trial 1	Clustered	Distributed	Clustered	Distributed
Trial 2	Distributed	Clustered	Distributed	Clustered

Table 8-1: Showing the counter-balanced order of trials run within the study 4 design.

Before entry participants were asked to attempt to find an individual window as their primary task. In this way the impact of the configuration and applied adaptation could be evaluated, along with influences of the display and decision making in identifying feedback.

After each interaction with the system the participants would complete a structured interview, Appendix [F1 Interview Questions], immediately followed by the alternate condition, and again followed by a structured interview. The entire experience would last around 10 minutes and would be recorded via two video cameras and Dictaphone. The actors would use the time between trials to prepare video cameras and adjust their configuration to ensure the participants could re-enter the space immediately after interview. The participant would not be informed of the alternative configuration and would be instead be prompted to "repeat" the trial. This would give the indication of the same configuration but would instead lead to testing pre-planning, awareness and decision making upon entry.

8.2.2 Approach to Results and Analysis

As the nature of study data has been relatively complex up until this point, the analysis techniques have considered a thematic representation of underlying factors to inform the general use. This study now considers how feedback is presented relative to entry and the manner in which this informs approach, further, there are considerations for user and display behaviours which influence these factors to inform the design and use of this approaches. This requires a more thorough analysis of the role and impact of the system.

The objective of this study were;

- Presentation of detailed Vignettes to describe key clusters in user Behaviours
- Expanding the analysis to consider factors of the display and user behaviour, identifying critical aspects of system design to actively support user interactions
- Identifying the role of the position marker feedback and the minimum requirements for use with delayed adaptations

8.2.2.1 Overview of interactions

To assess the range of user behaviours all interactions were initially grouped based on the configuration of actors. The interactions with the system were separated in to three distinct phases; Entry, Understanding, and Landing, with behaviours encoded using a high-level key word description of behaviours, reporting and experiences of users, matched with the nature of on-going adaptation. These terms are described in further detail below;

Entry – The initial entry and orientation behaviour of the user. This considers the speed and direction of entry, the glance behaviour and on-going movement and adaptation of the display. This phase aims to highlight the initial factors of display layout and factors of social dynamics or interaction which may influence or inform the user. This phase begins to infer the decision making of the user in relation to the understanding phase and how this early behaviour might lead to learning and task completion. There is no distinct relationship to the adaptation between this phase and Understanding, but instead considered the behaviour before there is a strong aspect of user engagement towards aspects of the space.

Understanding – Addresses the unfolding process of feedback of the user in relation to factors of the display and adaptation. This considers how the observed movement might indicate learning and engagement with aspects of the system and summarises how the user has transitioned from their initial experience to their final position and state of interaction.

Landing – Identifying where the user finally aligns to and/or arrives at the display and the key factors which informed this decision. This considers how the user ultimately achieves or fails the task and the driving factors in the users' understanding and insight to the experience. While the success or failure of the task can be ultimately identified, the entire nature of the interaction must be considered in this final stage, from initial aspects of Entry through Understanding to task completion. In this manner the key points are identified.

An examples of a users' interaction and supporting description is shown below (Figure 8-4);

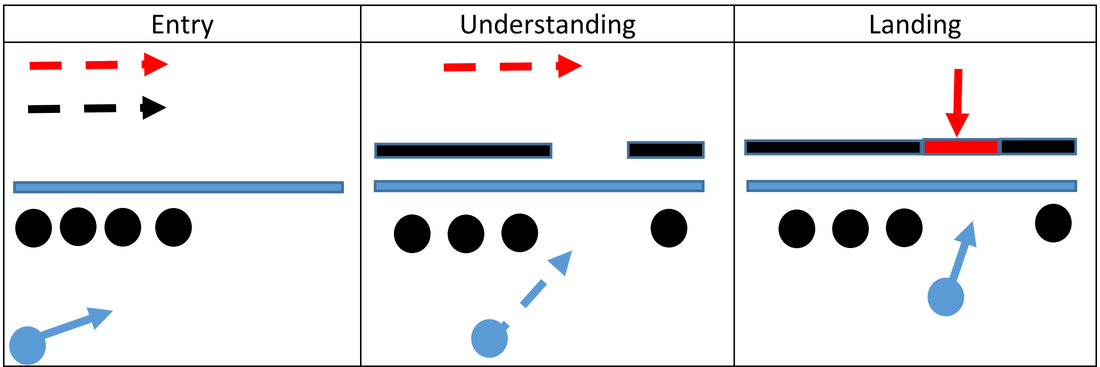


Figure 8-4: Top down view of the three phases of user interaction depicting the Entry, Understanding and Landing phases of the interaction for a single user.

Here the position of the user and actors are shown, with movement of the position marker as the red arrow and adaptation shown as the black arrow with the final position of windows also shown as red and black bars respectively. The full set of examples of each interaction and groupings can be seen in Appendix [F2 Interaction Overview].

Corresponding Key Word Description:

- Enters – Small clear **adaptation** on right hand end of display - User initially responds to **adaptation** – User slows upon entry – User approaches the adapted gap - **Position marker** offers fine grained approach position.

The corresponding long form key word description of this interaction would then be;

- Entry – User moves at a medium pace (blue arrow) with glance behaviour to the display – The position marker (red dashed arrow) is moving in line with the user – The **adaptation** is triggered (black arrow) and begins to move to the right.
- Understanding – The **adaptation** on right hand end of the group continues (single actor moving right) – Fourth actor moves to the right – User is already aware of the adaptation.
- Understanding - User has initially responded to **adaptation** (glance behaviour) during Entry – User slows and orientates to the adapted gap (dashed blue arrow) – Position marker moves past the user position towards the gap (red dashed arrow).
- Landing - **Position marker** offers fine grained approach position (red arrow) and moves directly above the new window position – New window is clearly shown (red rectangle) – User approaches the location and stands ready to engage.

The key word analysis shows the timing and approximate influence of the factors of the display for this scenario to aid in the simplification and comparison. The key word approach initially presented the critical behaviours of these elements as they happened, using high-level description to try and draw further meaning and relation between factors.

The high-level descriptors were broken down in to two parts, considering; User centred behaviours, and factors of the display and social implications from interactions and actors' movements. This sought to identify the critical behaviours in each of the three interaction stages, drawing out cause and effect ultimately leading to success or failure of the task.

Users exhibiting similar behaviours and outcomes were then clustered to establish an initial distribution of users, interaction behaviours and factors of the system. These simple descriptions proved to capture enough information between user behaviour and system function but did not provide a significant clustering response. In many cases there were significant parallels between multiple individual users, however, the initial clustering resulted in nearly as many clusters as there were instances of user interaction in each group.

8.2.2.2 Key word clustering and associated Behaviours

A further simplification was applied to draw meaning from the clustering approach. This focussed on a very limited number of factors of Display and User behaviour from the key word approach. Key words ("**highlighted**" above) were used to describe key factors and changing behaviours over time. A full list of the key words is presented below (Table 8-2).

Key Word	Description
Adapt	The user is following a clear adaptation of the display
Jumble	There is a jumbled adaptation – limited but unclear movement of windows
Marker	The user is watching and moving with the position marker
Conf.	The user is "confidently" moving – limited glance with quick direct movement
Watch	The user is watching the display – stationary or moving slowly
Observe	The user has identified and adaptation or the position marker – focussed
Correct	The user moves from their position to the window based on final layout
Moves	The user makes a movement for their own reasons – no relation to the display
First	The user moves to the first adaptation position
Second	There is a second adaptation – the user moves to the second adaptation position
Responds	The user responds to a local movement of the marker
Window	The new window has a strong presence or the user responds to the window
Ignore	The user ignores the marker or new window near them or moving past
Confused	The user is confused – lots or movement and investigation – appears unsure
Hidden	The new window is hidden from the user by existing windows
Engage	The user has identified and is moving towards the final location
Follow	The user is following the movement of the position marker

Table 8-2: Key Word description of the high level simplifications of user interactions.

These key words describe the highest level of abstraction for both display and user actions and behaviours and were applied to each interaction separately. This approach for the example given above is shown below (Table 8-3):

	Entry		Understanding		Landing			
Cluster	Display	User	Display	User	Display	User	Freq.	Behaviour
Achieved								
1	Adapt.				Marker		4	2

Table 8-3: Showing the key word analysis across the three phases of interaction for a single user as represented by the top down view in Figure 8-4.

The key word "**adaptation**" is seen in the Entry phase and there is no clear indication of any additional or changing factors further influencing the user until the "**Position Marker**" is identified in the Landing phase. The general forms of behaviours were later used to define a higher level of description in greater detail, leading to this cluster of interactions being defined as Behaviour #2. The process of abstraction will be discussed in a greater detail later and is presented as a series of detailed Vignettes within the Findings section.

Where a participant would exhibit similar behaviour or influences from the display these interactions would be clustered together to allow a frequency of responses to be identified. The resulting table for the entire user group is shown below (Table 8-4):

Novice Clustered-Dist (N-Clust-D) – Novice Clustered First – (NCF) – 9 Achieved – 2 Failed								
	Entry		Understanding		Landing			
Cluster	Display	User	Display	User	Display	User	Freq.	Behaviour
Achieved								
1	Adapt.				Marker		4	2
3	Adapt.		Adapt.		Marker		1	2
4		Conf.		Conf.			1	4
5		Conf.	Adapt.		Marker		1	3
6		Conf.	Adapt.	Watch	Marker		1	3
7						Correct	1	5
Failed								
2			Adapt.	Watch		Moves	2	6

Table 8-4: Showing the key word clusters identified across the three phases of interaction for Novice users in the Clustered configuration as their first interaction.

The variety of system functions which influenced user behaviour were then addressed. Where the "**highlighted**" factors were simplified behaviours used to construct (Table 8-4), the initial clustering approach was formed around the similarities in entry. Changes across the three phases of interaction were used to address divergences in users behaviours, which is what initially resulted in high numbers of instances and low frequencies.

To further expand upon the understanding of the system these tables were expanded to include richer detail and "positive" (shown in green) and "negative" (shown in red) influences throughout. An examples of Clusters #1 and #2 from (Table 8-4) are shown and expanded upon (Table 8-5). It should be noted that #1 is Achieved and #2 Failed in the task.

Novice – CLUSTERED – Dist (NCF)							
	Factors of Entry	Entry Behaviour	Factors of Understanding	Understanding Behaviour	Factors of Landing	Landing Behaviour	Task
1	Small adaptation of display with single actor move. (7 users)	Gentle entry, medium pace. (7 users)	Position marker is moving from left to right.	User slows and begins to approach the new gap. (4 users)	Position Marker moves in to gap.	User identifies the marker and moves towards the gap. (4 users)	4. A
2			Secondary adaptation moves to the left.	User pauses to watch the adaptation. Does not approach the gap. (2 users)	Position Marker moves in to gap.	User moves towards second adaptation and cluster. Does not engage with marker. (2 users)	2. F

Table 8-5: Showing the expanded positive and negative key factor descriptions in the initial clustering approach for two clusters found in the Novice Clustered trial.

This shows the three phases of the interaction, with "Factors" describing the physical instances of the space and display, and "Behaviour" indicating the observed actions of the participant. These are stated separately for each phase. The "Task" column indicates the number of participants and if they Achieved or Failed (A/F) respectively. In Cluster #1, this is shown by 4.A, to indicate 4 persons Achieved the task.

As this table exhibits greater detail of the observed behaviour, but also specific details of the interaction, a simplified representation was used to minimise the volume of reported data. Where the Entry columns of #2 are left blank, this is due to the "Factors" and "Behaviours" of #2 being the same as those observed during Entry of #1, however, in #2 there was no clear indication the "adaptation" had been identified and so it was omitted from the key words (Table 8-4). In #2 there was a clear impact in both "Factors" and "Behaviours" in the Understanding phase separating the two clusters.

In the above table (Table 8-5), the Entry behaviour of #1 indicated there were 7 users total in the group exhibiting the same entry behaviour. In the Understanding phase however, there are 4 users seen to perform behaviours attributed to #1, and 2 performing the actions of #2. This would indicate that a single user performed a different action and was subsequently separated in to another cluster (not shown in this table). By this process, the positive and negative influences of both display and user behaviours could be identified relative to Entry, Understanding, and Landing phases. These factors are considered later in the Findings to assess critical components of behaviour towards adaptation.

8.2.2.3 Altered interaction – Changes in identified Behaviours

Where the (Table 8-4) helped to describe the clusters via key word analysis, the secondary approach expanded upon key factors and behaviours throughout the task. This now presents a relationship between the abstracted Behaviours derived from Entry conditions and task completion to factors and behaviours of display and users across each phase of the interaction. Where the clusters describe an overarching behaviour, the three phases of the interaction describe how and why a participant may have changed between observed behaviour states i.e. users may enter in a similar manner yet drastically change their Behaviour through the interaction (Table 8-5). For examples, the table below (Table 8-6) summarises the Entry and Result Behaviours and factors for the change;

Novice Clustered – D – Changing behaviours and contributing factors				
Cluster	Freq.	Entry	Result	Factors
1	4	2	2	
2	2	2	6	Secondary adaptation – Draws user towards the cluster – Difficult to identify the marker or location of new window

Table 8-6: Example of the changing entry behaviours of users based on expanded key factors for two clusters identified in the Novice Clustered trial.

If we consider the outcome of Cluster #1 from (Table 8-4), we see this form of interaction was classified as Result - Behaviour 2 ("Engaged" behaviour with aspects of the system informing the interaction). When considering the Entry conditions of this cluster it was also found to match Behaviour 2. As such there were no critical factors or behaviours that influenced or changed the Entry relative to the classified outcome.

Alternatively Cluster #2 was ultimately classified as Result - Behaviour 6 ("Not Engaged" user-led decision making), yet also exhibited the same Entry conditions as #1. This would indicate significant influences of the system and/or user which caused a change, or "Altered" interaction from Entry Behaviour to the final classification. By considering the reported findings from (Table 8-5) we can begin to identify the influencing actions and frequency distributions for why an interaction may shift through these Behaviours. Examples of all tables described above can be found in the Appendix [F3 Interaction Overview Tables].

With considerations of each of these analysis approaches this leads us to be able to consider;

Factors of Altered interactions;

- What is the role of the position marker – does it support the interaction or are there aspect which influence users leading to "Fine-tuning" as described by Behaviour(2)
- What is stopping users engaging with the system after the initial Entry Behaviour leading to a break in the flow and a staggered interaction
- What leads a user to fail the task or break from the interaction

Key changes and distribution of Behaviours and Altered interactions;

- What are the major changes in clusters between both configurations and why
- What are the positive and negative influences in both configurations
- How many users enter in Behaviour (1) and stay in that state
- How do users change in to and out of Behaviour (1) and what are the factors of the position marker feedback which influence this

8.2.3 Summary

This section has now presented the approach of the investigation, and methods employed in handling and analysing the findings of this study. The steps taken have considered the range of observed behaviours across all interactions leading to a key word analysis. This was used to initially cluster the interactions and derive the overarching interaction Behaviours, which are described in detail in the Findings section.

The analysis then went on to expand the key word descriptions as three distinct phases of the interaction. This grounded the task orientated interaction to aspects of "Engaged" system-led user behaviour informing the interaction, compared to "Not Engaged" with the system or space and decision being user-led. Where the user showed a level of engagement with the display we could consider aspects of changing or "Altered" Behaviours between Entry and the final classification of interaction Behaviour as a method to more accurately determine the role and influence of display and user-led behaviours in display use. This ultimately leads to a framework to describe a range of social and spatial behaviours relative to the user and system for both the between and within elements of the study design, shown below (Figure 8-5);

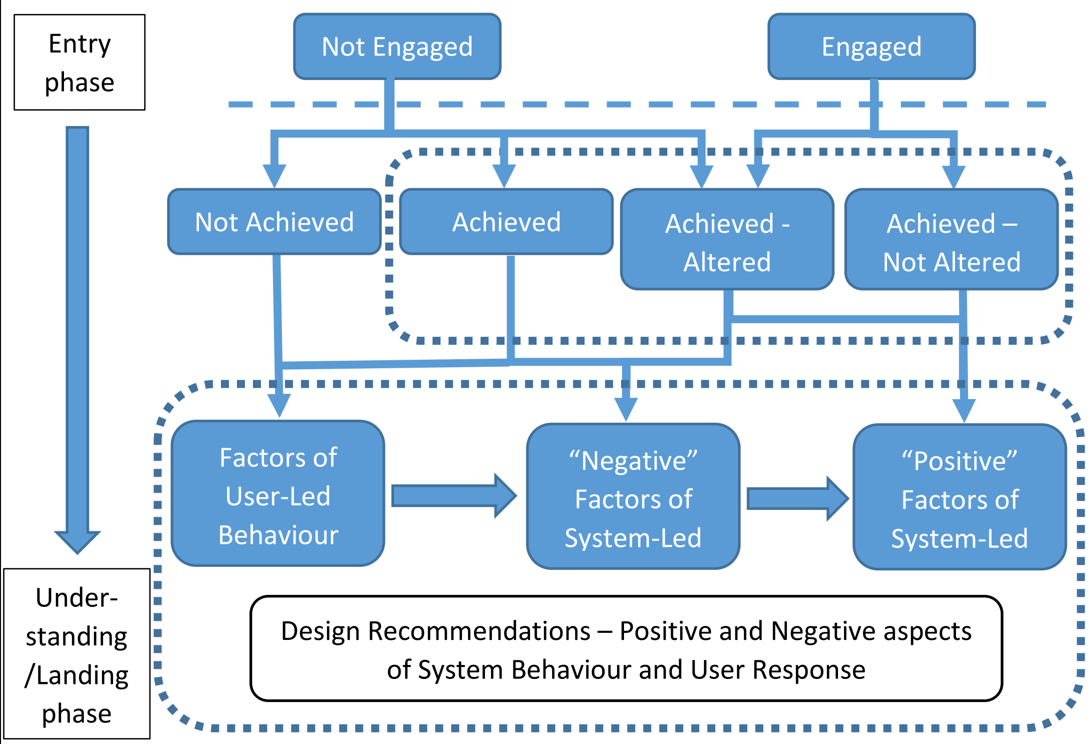


Figure 8-5: Showing the framework of relationships between influencing factors of system use between user and system led interactions to identify issue of interaction and response.

This now situates the role of maintained Behaviours, either through user decision or system interaction, as a baseline for user distribution, compared with Altered Behaviour from Entry indicating edge cases for the design and use of these systems. This places the user at the focus in approaching the task and the simplification and discussion of key system and user factors to inform design recommendations. These include;

- Factors of User-Led Behaviours which do not result in achieving the task requiring further considerations for design and system behaviour.
- Factors of User-Led Behaviours which resulted in achieving the task and the role the System in recovery.
- Short-comings or "negative" aspects of the System which allowed for, or led to users not achieving the task.
- Short-comings or "negative" aspects of the System which "Altered" the interaction Behaviour from a "positive" state to some other form of engagement.
- Influential or "positive" aspects of the System which supported users, this includes;
    - Aspects of feedback to inform understanding.
    - Wider influence over the space to draw user engagement from User-Led.

This now describes the full range of interaction behaviours to identify how and where system function can be applied, its effectiveness in a range of scenarios, and the nature of interaction and engagement with and around these systems for future work. The findings of this study will now be presented following the described approach.

8.3 Findings

The following sections considers the data captured after applying the design approach described above. Each of the above steps is applied with considerations of their meaning. The findings are presented as follows;

- Vignettes of interaction Behaviours – These describe the main Behaviours identified across all interactions.
- Distribution of Behaviours – Identifies the range of Behaviours and positive and negative factors of use.
- Key changes and distribution of factors of Altered interactions – This considers all key word and user reporting of influencing factors in examples of Altered interactions.
- Considerations of Positive and Negative factors in Altered interactions – These describe the influences and weighing of both display and users behaviours in achieving or failing the task.

Each of these points will be considered in turn.

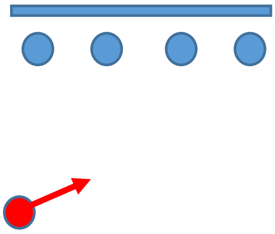
8.3.1 Identifying the interaction Behaviour Vignettes

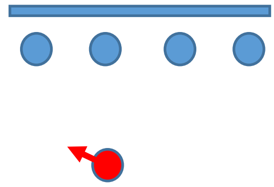
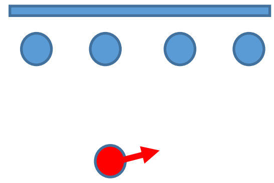
After thematic simplifications there were six distinct forms of interaction Behaviours that were identified. These Behaviours describe the nature of entry and approach based on user decision making and factors of display leading to the landing phase and are grouped according to system- or user-led. These are now described in more detail;

8.3.1.1 System led Behaviours

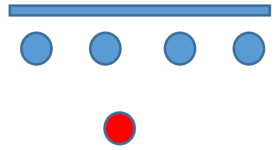
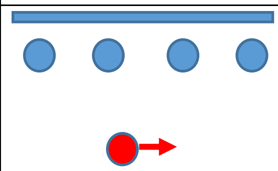
These describe aspects of the system leading the interaction or offering significant feedback to inform decision making in achieving the task. These consider the design of the study relative to behaviours seen in previous trials;

Behaviour 1: These users exhibited factors of an “ideal” expected interaction based on the design of the study. The initial entry behaviour was carefully considered, with high levels of investigation and awareness of the display and layout of the space and actors. Many users were able to interact with the position marker in the responsive state before it switched to a leading role. All users in this group appeared to respond to leading movement of the marker in identifying the point of engagement and achieving the task (Table 8-7).

<table>
<tr><th>Camera Still</th><th>Top Down view</th><th>Description</th><th>Timeline - Code</th></tr>
<tr><td></td><td></td><td>The user enters the space and walks towards the centre X = 2.5, Z = 3.5.

Glances towards the position marker</td><td>0:00 (1:16)
Enter
|
|
|
|
|</td></tr>
<tr><td></td><td></td><td>User moves in line with marker to the first gap.
Deliberate move to the left while watching the marker.</td><td>0:02 (1:18)
Watch
Interacts
|
|
|
|</td></tr>
<tr><td></td><td></td><td>Watching marker move to next gap.

User immediately follows the marker.

Aligns to window</td><td>0:03 (1:19)
Corrects
|
|
|
Aligns
|</td></tr>
<tr><td></td><td></td><td>User moves towards the window</td><td>0:06 (1:22)
Approach
|
|
|
|
|</td></tr>
<tr><td></td><td></td><td>User side-steps in front of the window and marker.

Returns to inline position.</td><td>0:07 (1:23)
Investigate
|
|
Return
|
End</td></tr>
<tr><td colspan="4">Table 8-7: Vignette detailing Behaviour 1 as identified through clustering including; screenshots, birds eye view, description and timeline.</td></tr>
</table>

In this instance there was no clear adaptation of the display as the gap was sufficient in forming a new window. The user can be seen to interact with the position marker and is led to the location without the need for adaptation. The user does not approach the display directly as this may be a factor of the narrow gap, however, the user has identified and approached the window.

Behaviour 2: These users exhibited slow and considered entry behaviour. There was an early engagement with the adaptation and users identify a relationship to display changes. These users did not engage with the marker in the same manner as Behaviour(1) which was a critical aspect of the system design and feedback. Users aligned themselves to gaps and clear channels between actors and identified the position marker later in the experience as a confirmation for their point of interaction (Table 8-8).

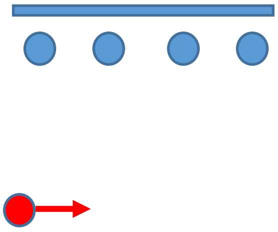
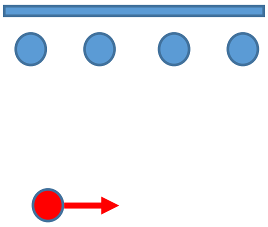
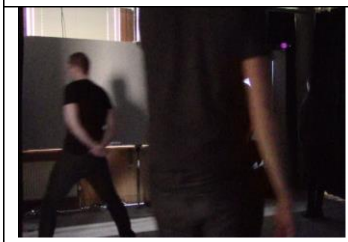
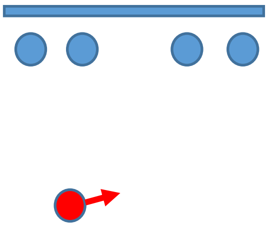
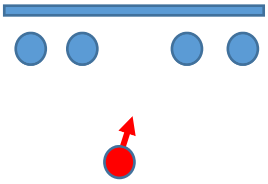
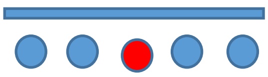
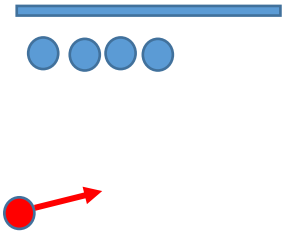
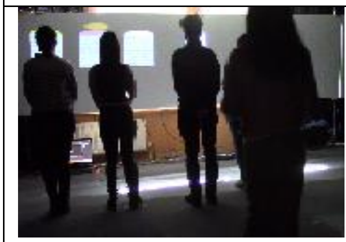
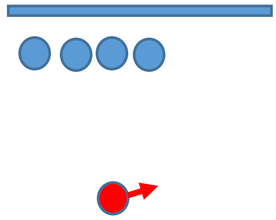
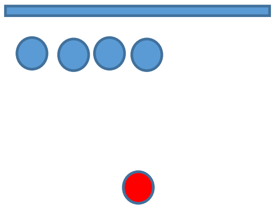
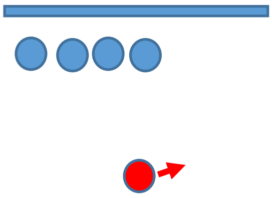
Camera Still	Top Down view	Description	Timeline - Code
		The user enters the space and walks parallel to the display at Z = 4.5. The user passes X = 0	0:00 (1:04) Enter | | Continue | |
		The adaptation begins – Window 2,3 make a large move quickly left/right. The user continues walking parallel.	0:02 (1:06) Adapt | Actors Respond | |
		Actors 2,3 move left/right. User has a half step with small change in direction.	0:04 (1:08) Aware | | Respond | |
		Fully orientates towards the gap. Position marker is to the left of the user, moving right.	0:06 (1:10) Target | | Engage | Approach
		Window appears. User approaches display directly and joins the line. There is a large gap and no impact from actors.	0:09 (1:13) Line | | | | End

Table 8-8: Vignette detailing Behaviour 2 as identified through clustering including; screenshots, birds eye view, description and timeline.

Users classed in this Behaviour reported little to no awareness of the position marker in their early entry or approach. Layout and adaptation were the key driving factors, with the position marker being identified later confirming decision making to encourage approach.

Behaviour 3: These users showed medium to fast entry with a low level of engagement with the display or adaptation. User were seen to enter and quickly slow or stop as there was an adaptation. This was different from Behaviour(2) which was a more streamlined engagement. Once stopped users gained more understanding of the system before responding to gaps and channels, before resolving landing due to the window (Table 8-9).

<table>
<tr><th>Camera Still</th><th>Top Down view</th><th>Description</th><th>Timeline – Code</th></tr>
<tr><td></td><td></td><td>The user enters quickly and walks towards the centre X = 2.5, Z = 3.5.

Glances towards the position marker</td><td>0:00 (0:58)
Enter
|
|
Continue
|
|</td></tr>
<tr><td></td><td></td><td>User has moved behind the cluster, X = 1.7, Z = 3.7.
User noticeably slows and observes marker move in-line.</td><td>0:01 (0:59)
Slows
|
|
Marker
In-line
|</td></tr>
<tr><td></td><td></td><td>User stops as marker moves past their location.</td><td>0:02 (1:00)
Stops
|
|
Observes
|
|</td></tr>
<tr><td></td><td></td><td>The user watches the marker move to the right.

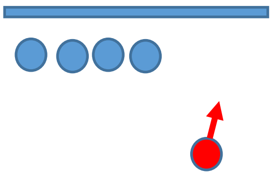
User takes a single step following the marker.</td><td>0:03 (1:01)
Watching
|
|
Step
|
|</td></tr>
<tr><td></td><td></td><td>The user takes another half step to the right.
The window is shown and the user begins to approach directly.</td><td>0:06 (1:04)
Approach
|
|
|
|
End</td></tr>
</table>

Table 8-9: Vignette detailing Behaviour 3 as identified through clustering including; screenshots, birds eye view, description and timeline.

While users may show an awareness and relation to the marker, there is no relationship drawn to the space or decision making. Instead this group would completely stop in the space and wait for a clear adaptation or point of interaction to be presented. This approach and landing Behaviour is characterised as system-led, but not a streamlined experience.

8.3.1.2 User led Behaviours

These Behaviours describe greater user decision making in Entry. This may not mean zero engagement with the system, however, the nature of these interactions can be characterised by user decisions defining the Entry and Understanding, and Landing becoming emergent.

Behaviour 4: Users exhibited direct (confident) movement when entering with no apparent interaction with the display or configuration. The user moves directly in to the space to a location at the display. Once they are at this location new content is shown with them having no expectation outside of their initial decision. There is little to no engagement with factors of the display as seen in the previous Behaviours (Table 8-10).

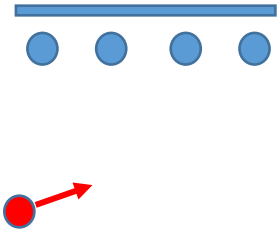
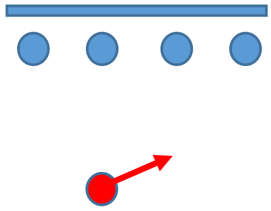
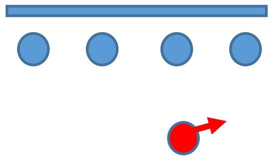
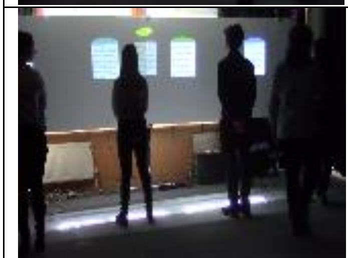
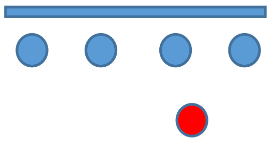
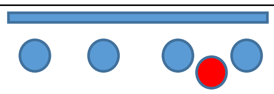
Camera Still	Top Down view	Description	Timeline - Code
		The user enters quickly and moves directly towards the right hand corner of the display.	0:00 (0:53) Enter | Direct | | |
		Small movement of window three, user glances at movement. User moves directly towards right hand corner.	0:01 (0:54) Movement | Glance | | |
		User approaches actor three and makes a deliberate move to the right side of the user.	0:02 (0:55) Approach | | Moves | |
		New window is shown at the centre. User moves to the right of actor three.	0:03 (0:56) Window | | Moves | |
		User moves in to the gap and joins the line. There is no glance behaviour across the display.	0:06 (0:59) Line | | | | End

Table 8-10: Vignette detailing Behaviour 4 as identified through clustering including; screenshots, birds eye view, description and timeline.

While this Behaviour does lead to achieving a window the outcome is coincidental although in-line with the underlying system design. There is little to no interaction with the system.

Behaviour 5: This group is identified by the user entering the space and investigating the display but not making a connection to the adaptation, position marker or movement of actors. The user spends a significant amount of time investigating the space before identifying the new window and position marker. The user then makes a significant movement through the space to correct from their initial position (Table 8-11).

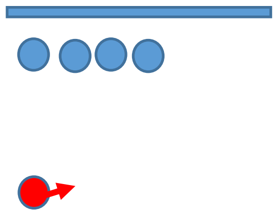
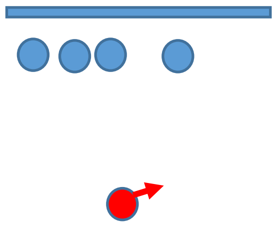
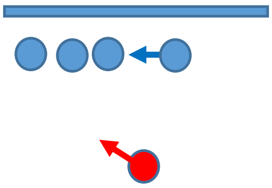
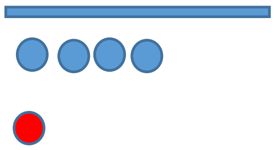
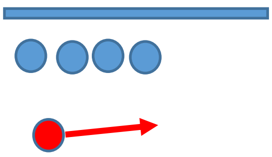
Camera Still	Top Down view	Description	Timeline - Code
		The user enters and there is an early initial adaptation moving actors' right. User is orientated away from the display.	0:00 (1:02) Enter | Adapt | |
		Adaptation begins to move actors back to starting places. User begins to orientate towards the display.	0:01 (1:03) Adapt | Actors Respond |
		Actor 4 moves quickly to the left. User makes a full change in direction towards the left end. Marker moves right.	0:03 (1:05) Ad Change | Dir Change |
		User approaches far left and stops. New window is shown on the right. User observes display.	0:06 (1:08) Stop | Observes | |
		User notices window and moves directly to the right to engage. User ultimately lands at the new window.	0:07 (1:09) Notices | Moves | End

Table 8-11: Vignette detailing Behaviour 5 as identified through clustering including; screenshots, birds eye view, description and timeline.

There is an aspect of user decision making requiring correction which defines this behaviour. Aspects of the system which may have led to this are considered in the findings.

Behaviour 6: This group exhibited several factors of Behaviours (2 & 3), where entry was slow to medium with consideration of the adaptation and actors. The major distinction is in the users understanding and response to these factors similar to Behaviour (5). As the adaptation is creating a gap and a new window is shown the users make a subjective decision to move away from this location and approaches an alternative location (Table 8-12).

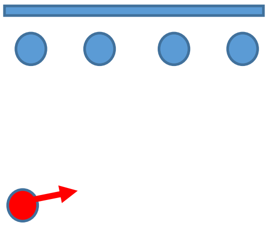
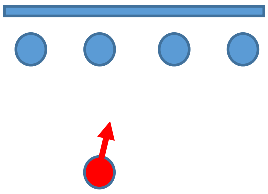
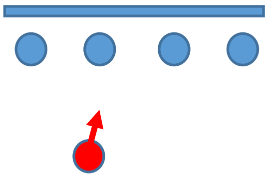
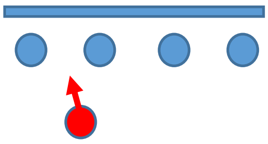
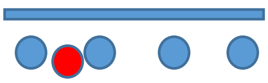
Camera Still	Top Down view	Description	Timeline - Code
		User enters moving slowly toward the centre of the space.	0:00 (0:50) Enter | | | | |
		User changes orientation towards the display. Marker is in-line with the user position.	0:02 (0:52) Orientation | | | | |
		Small glance at the marker as it moves past the user position. No change in approach speed.	0:03 (0:53) Glance | | | | |
		User turns back to the display and continues to approach the first gap. No further glances to the marker.	0:04 (0:54) Turns back | | Approach | |
		User moves slowly to the line. The user stands slightly behind the line and looks towards window one.	0:06 (0:56) | | Line | | End

Table 8-12: Vignette detailing Behaviour 6 as identified through clustering including; screenshots, birds eye view, description and timeline.

These Behaviours are representations of the general actions and interactions of users based on Entry and transitioning to the Understanding phase leading to Landing. These Behaviours do not preclude achieving the task, but are abstract considerations of the driving factors of the system within the interaction.

Following the simplification and key word clustering in identifying these Behaviours a frequency distribution for Behaviours was found to begin to describe the nature of system use, this is described in the next section.

8.3.2 Distribution of Behaviours from the key word analysis tables

Following the key word descriptions of each interaction a Behaviour classification was applied, with any critical deviations identified in achieving a simple Behaviour distribution.

Critical deviations or sub-categories were marked with additional lettering to highlight the interaction i.e. Behaviour 1 (b/c), along with a supporting description. While the frequency of these instances was low these give insight to issues of system design or interaction and allow for erroneous data to be initially removed for a first pass analysis.

In cases where "User Confidence" caused a difference in the behaviour, but did not define the interaction i.e. Behaviour 4, this has been identified as "c" i.e. Behaviour(1-6)c – User Confidence. This may only be evident within part of a phase or action and not define the overall classification. This can be in the role of pre-emptive or direct approach with limited engagement, either before or after a critical component of the display or interaction has been identified leading to the final classification.

The final indication used was "f" to show that the user failed the task but was not resigned to Behaviour 6, where failure can be attributed to a display factor or error in the adaptation. These failures have been identified separately to track frequency and relation to system use.

The distribution of Behaviours based on the Key Word analysis is now presented below.

As each group has experienced each configuration in a counterbalanced approach, this is denoted by the description at the top of each table i.e. Novice - CF being the Novice group in the Clustered configuration as their First experience. Both interactions for this group would be read as NCF, NDS and so on. The first table (Table 8-13) shows the overall distribution of Behaviours, with each configuration and supporting descriptions for secondary behaviours and failures shown in the Appendix [F3 Interaction Overview Tables].

Study	NCF	NCS	RCF	RCS	Freq.	NDF	NDS	RDF	RDS	Freq.	Sum
Behaviour											
1			6	5	11		5	5	4	14	25
1b			1		1						1
1f			1		1						1
2	5	3		2	10	8		4		12	22
2b		5			5						5
2c			2		2		2		3	5	7
2f		2			2	1		2		3	5
3	2			5	7	1				1	8
4	1				1		1			1	2
4f								1		1	1
5	1	1			2		1		2	3	5
6	2	1	1		4	2	2		2	6	10
Total	11	12	11	12	46	12	11	12	11	46	92

Table 8-13: Combined table showing the distribution of Behaviours in all groups.

With the (7) failures (f) relating to aspects of system or user behaviour removed to be considered separately, and the secondary sub-categories combined in to the overall Behaviours, the final distribution of Behaviours across all trials is shown below (Table 8-14):

Study	NCF	NCS	RCF	RCS	Freq.	NDF	NDS	RDF	RDS	Freq.	Sum
Behaviour											
1			7	5	12		5	5	4	14	26
2	5	8	2	2	17	8	2	4	3	17	34
3	2			5	7	1				1	8
4	1				1		1			1	2
5	1	1			2		1		2	3	5
6	2	1	1		4	2	2		2	6	10
Total	11	10	10	12	43	11	11	9	11	42	85

Table 8-14: Combined table showing the distribution of Behaviours in all groups with simplified secondary factors and failures removed.

In total 74 users completed the task, with 17 total failures. Of the failures, 10 are described by Behaviour 6, with a further 7 being identified by aspects of the system or user error i.e. Behaviour[(1)x1, (2)x5, (4)x1]f. These failures were identified [(1)x1, (2)x5] as a direct result of poor adaptation i.e. the new window being hidden from the user, whereas [(4)x1] was due to the user making a confident but incorrect decision.

The distribution of Behaviours between the two groups saw Novice users presenting a wider array of interactions compared with the Repeat group who are mainly within the system led behaviours, specifically Behaviours (1&2). In total there were [5 & 21] [Novice/Repeat] users respectively in Behaviours 1 across all trials, with Repeat users showing far greater awareness of the position marker and a correct interpretation of its meaning, making up 80% of Behaviour 1 classifications. Of the 5 Novice users in Behaviour 1, this was seen in the second interaction and may indicate learning or greater awareness between trials.

This increase in Novice user interpretation was seen in the Novice Distributed Second (NDS) in Behaviours (1&2), suggesting that the Clustered configuration may offer an improved learning opportunity, given the simpler layout and more pronounced relationship of the position marker to the final window position. Conversely the Distributed condition First (NDF) may be a more cognitively challenging situation to interpret this relationship, and so the meaning may be missed. The distribution of Behaviours (1&2) in Repeat users is approximately equal between interactions, with a slight reduction in RDS tending towards user-led, potentially due to expectation of the interaction and contravening the above point, although this may be due to an increased confidence by Repeat users in the interaction.

Considering the distribution between the two configurations, Behaviours (1&2) are almost exactly equal suggesting users are able to interpret the interaction equally well in both. The distribution is, however, skewed when looking at the difference in user-led Behaviours (4-6), with the Clustered showing more users in Behaviour (3) i.e. slowing or stopping to observe, compared with Distributed where the weighting is in Behaviour (6) i.e. entirely user-led. This may be due to the Clustered case being less densely populated allowing for greater interpretation, vs. multiple points of interaction and user decision in the Distributed case.

When combining Behaviours (1&2) we see [26 & 34] or 60/85 = 71% of overall interactions, showing that the underlying adaptation, along with the addition of the position marker, plays a significant role in the interaction. If we look at the breakdown of interactions between Novice and Repeat users along with the between case for both interactions (Table 8-15):

Study Behaviour	NCF	NDS	NDF	NCS	Freq.	RCF	RDS	RDF	RCS	Freq.	Sum
1		5			5	7	4	5	5	21	26
2	5	2	8	8	23	2	3	4	2	11	34
3	2		1		3				5	5	8
4	1	1			2						2
5	1	1		1	3		2			2	5
6	2	2	2	1	7	1	2			3	10
Total	11	11	11	10	43	10	11	9	12	42	85

Table 8-15: Table showing the distribution of Novice and Repeat Behaviours with between conditions for both interactions.

Looking at the between cases for first and second interactions there is no significant increase in Behaviour distribution to Behaviours (1&2). With an approximately equal split [28 & 32] Novice and Repeat users in Behaviours (1&2), suggesting that a large portion of users can be supported through adaptation of the display without any significant prior experience. This said, the impact of the position marker in this form is limited to users with increased awareness stemming from experience or expectation, so only providing additional impact in 21/60 = 35% of interactions when the [5] repeat Novice interactions are not considered, i.e. Repeat user or those who have an expectation of additional system components.

This suggests that while adaptation and feedback can support approach, there are 29% of cases where either; the user waits for a clear point of entry at the display, or has decided where to interact without regard for feedback or leading effects. This can be related to feedback not clearly informing users where or when adaptation may take place in supporting more direct approach – Behaviour (3). There are also considerations of user-led decision making and levels of awareness relative to entry – Behaviours (4-6).

For all other Behaviours, 8/85 = 9% are Behaviour (3), 2/85 = 2% Behaviour (4), 5/85 = 6% Behaviour (5), and 10/85 = 12% Behaviour (6), with [15 & 10] Novice and Repeat users account for all of these. While Behaviour (3) shows a more measured approach it is predominantly system-led, with users taking time to interpret the display and gain meaning before approach, the interaction is not immediately streamlined and may suffer from issues of further adaptation or other user behaviours as Understanding and approach are taking place. However, combined with Behaviours (1&2) we see 68/85 = 80% of all interactions are supported in some way by the system in its current form.

Considering the remaining 20% of user-led interactions, the Understanding phase is not directly supported by feedback and adaptation based on Entry, although Behaviour (5) (6%) suggests change supports recovery. In these cases there is a strong indication that adaptations must be more carefully linked to on-going behaviour, with 20% user-led interactions, Behaviour (4) (2%) being serendipitous, Behaviour (5) (6%) being recovered, and Behaviour (6) (12%) being lost, the potential impact of adaptation to on-going users presents an unacceptable design consideration.

With 80% of users responding to the system and a further 8% eventually achieving the same interaction, although this is not guaranteed, there is a need to investigate how feedback can initially captures attention in the landing zone, conveys richer detail in meaning, and indicating where adaptations will take place. While the appearance of a new window and adjustment provides strong feedback during approach there may be alternative mechanisms to support this without adaptations having to be applied, so preventing false positives in 20% of cases and allowing for a confirmation to be made beforehand.

8.3.2.1 Summary and Considerations of Positive and Negative factors of configurations

Considering the Clustered configuration users were previously seen to identify the cluster as a highly dense on-going interaction and so separate from their interaction. Du to this users would initially ignore the left hand end of the display and miss the interaction with the position marker, giving no indication of the responsive state or the meaning of the transition to the leading behaviour. This limited understanding or opportunity for interpretation during initial Entry, with the gap encouraging confident direct approach, leaving users to wait for the adaptation or additional feedback on the display.

As the adaptation was not immediate upon Entry users entering quickly would then stop to consider the display when there was no obvious change. This was the case for both Novice and Repeat users, although Repeat users would tend to exhibit more confident initial Entry. The positive outcome of the cluster would be to draw attention to the left side of the display, in turn helping to identify the position marker and offering a component of feedback. The time delay between Entry and adaptation presents an interesting factors of the cluster in drawing user attention, but also runs a risk of encouraging Honey-Pots and further clustering.

With the Distributed configuration the larger number of gaps and on-going users initially slows Entry Behaviour, as users are likely assessing multiple factors of the space. This greatly reduce the awareness of the position marker or learning effects between trials. In this configuration, the time delay before adaptation presents a serious issue for users, where their initial Entry is not immediately supported and there are multiple points for interaction, there may be a subjective decision made to change the Entry and approach direction before there is a clear adaptation. The greater distribution of on-going users after approach further limits the ability for users to identify any change and so recovery become more challenging.

The strongest indication in both cases is the need for immediate and understandable feedback from the position marker. As the adaptation is delayed there is no alternative opportunity to identify the meaning of change in state of the position marker, and so a constant responsive condition would prove extremely helpful. This may go some way to combat issues of users becoming separated from the prediction where they change their Entry and approach Behaviour.

While this section has initially characterised the distribution of Behaviours across the entire interaction, there are multiple examples of complex interactions and changing Behaviours between Entry and task completion. These Altered interactions are now considered.

8.3.3 Key changes and distribution of factors of Altered interactions

This sections will now consider how, when and why changes in user Behaviours may have taken place and the specific elements of the system and user decision making within this.

Where the initial approach was to identify the nature of each Behaviour across the three phases, described by the Key Word analysis and Behaviour Vignette’s, these do not account for the subtle factors of individual interactions (Table 8-5). Where the Key Word simplifications group users by similar Behaviours there are also distinct individual factors.

The detailed descriptions (Table 8-5) grouped users based on Entry before identifying diverging critical aspects based on both observation and reported factors. This approach indicates significant influences from factors of the system and user decision between Entry and their overall classification. A comparison of the Entry Behaviour and final classification was carried out to identify the distribution and reasons for these Altered experiences.

A summary of Altered and non-Altered experiences is shown in the table below (Table 8-16).

Distribution of Altered and Non-Altered interactions							
	1	2	3	4	5	6	Total
Clustered							
Altered							
Start	2	13	1	11	0	0	(27)
End	4	7	7	1	3	5	27
Not-Altered	8	11	0	0	0	0	19
Final	12	18	7	1	3	5	46
Distributed							
Altered							
Start	1	17	5	0	0	0	(23)
End	5	8	0	1	3	6	23
Not-Altered	9	12	1	1	0	0	23
Final	14	20	1	2	3	6	46

Table 8-16: Showing the distribution of altered and non-altered interactions for both configurations with the altered start and end Behaviours indicated.

In total there were 50/92 = 54% interactions exhibiting Altered Behaviours, with 27/46 = 59% and 23/46 = 50% interactions classified as Altered in the Clustered and Distributed configurations respectively. This considers all changes in Behaviours of users from the Entry state through Understanding and the overall classification at Landing.

Looking at the distribution of non-Altered interactions (45% total) almost all are seen in Behaviours (1&2), with 2 other cases in the Distributed configuration. This suggests that almost half of users enter the space and are able to interpret and follow the interaction to achieve a window, however, given the total of 80% of users seen to achieve a system-led interaction we must consider the factors of Altered Behaviours leading to this increase.

In the Clustered condition we see approximately half of Altered users entering in either Behaviours (2&4), with (2) suggesting a more measured assessment of the display looking for some aspect of adaptation or feedback. Behaviour (4) indicates a confident user-led approach which is linked to the open landing area. The same issue is seen in the Distributed case where Entry is entirely related to system-led awareness, namely Behaviour (2). While there are multiple landing areas there are significant social factors to consider upon Entry and users are more inclined to identify factors of the display before making a decision.

Looking at the final classifications of Behaviour for the Clustered configuration there is a shift to a more evenly distribution between Behaviours (1-3), indicating that during Entry several users have noticed the position marker and are responding, several are following the display and adaptation without the marker, and the final group are waiting for a landing position to be presented. The issue is found in the 9/46 = 20% of users shifting to an entirely user-led interaction, with 10% either finding the window serendipitously in approach or having to correct after the adaptation, and 10% having no awareness of the new window. In the Distributed case there is a more general spread of Altered interactions across all Behaviours.

Considering a breakdown of the Altered Clustered interactions (Table 8-17).

Distribution of Novice and Repeat user Altered interactions in the Clustered condition						
Novice			Repeat			
Start	End	Freq.	Start	End	Freq.	Total
			1	1f	1	1
			1	4	1	1
2	2b/f	7				7
2	5	1	2	5	1	2
2	6	3	2	6	1	4
			3	1	1	1
			4	1	3	3
4	3	2	4	3	5	7
4	5	1				1
		14			13	27

Table 8-17: Table showing the distribution of Novice and Repeat user Altered interactions in the Clustered configuration.

The split between Novice and Repeat users [14&13] suggests there are inherent issues within the interaction, either in display behaviour or user interpretation and decision making. Addressing the secondary Behaviours (b/c/f) which had been omitted previously, 8 Altered interactions were seen to be directly related to the manner of presentation of the adaptation, with issues of windows incorrectly interacting or not fully displayed affecting the user decision. These are included in a later section considering design recommendations. After removing these values the indication is that Repeat users are better able to identify factors of the display and transition to a system-led interaction, with 9 of the Altered interactions moving in to Behaviours (1-3).

Of the other interactions, 10 are seen to lead users from Behaviour (4) in to direct interaction with the system, indicating that on-going adaptations in the space are able to capture user attention, however, there are considerations of the adaptation needing to be relatively situated based on the users Entry for this to be effective. The remaining 7 interactions see users initially enter in Behaviours (1&2) but transition in to user-led Behaviours (5&6). While correction is still an option, as seen with Behaviour (4) Entry, the issue is found in the timing and awareness of feedback and the adaptation during the Understanding phase. Where users do not engage with any meaning of the position marker or miss the adaptation the default behaviours are to explore the space through either clustering or general movement.

This strongly indicates that feedback must be far more explicit in its early relationship to users and meaning in the space, and that any adaptation or intention of adaptation should be clearly presented throughout the interaction, both offering a landing position and inferring further meaning to the actions of the position marker and feedback.

Applying the same breakdown to the Distributed case (Table 8-18).

Novice			Repeat			
Start	End	Freq.	Start	End	Freq.	Total
			1	6	1	1
2	1	4	2	1	1	5
2	2f	1	2	2cf	5	6
			2c	4f	1	1
2	5	1	2	5	2	3
2	6	1	2	6	1	2
3	2	2				2
3	6	3				3
		12			11	23

Table 8-18: Table showing the distribution of Novice and Repeat user Altered interactions in the Distributed configuration.

Again the split in Novice and Repeat user Altered interactions [12&11] is equal, with issues of the system and user decision making being averaged between both groups. After removing secondary and failed interactions (b/c/f) there are 5 users who are able to identify the marker, however, all others experience a reduction in system-led Behaviours, transitioning to user-led actions, with 9/23 = 39% moving from Behaviours (1&2) to Behaviours (5&6). In all cases this is related to users interpreting the meaning of the marker or layout at initial value to inform their approach. Once at the display users may continue to observe changes and correct, or will persist with their decision and revert to exploration.

The distributed condition proves to be more challenging for users in identifying and interpreting the meaning of the marker and adaptations which have taken place. With the looser formation of actors there is not always a clear line of sight to a new window or obvious movement due to adaptation, resulting in significantly reduced feedback. Further to this, there is no immediately obvious landing position to draw focus or encourage confident approach in identifying the window or correcting behaviours, as such, users can quickly become disconnected from both the position marker and any adaptation that take place where this does not align with their current actions. While the adaptation is related to their Entry, and was shown to draw approach in the previous trial, the short delay in presenting the adaptation allows for secondary decision making and shifting of focus resulting in feedback being missed and user-led Behaviours.

8.3.4 Considerations of Positive and Negative factors in Altered interactions

Separating the Behaviours according to the design of the investigation now considers how changes in system-led and user-led Behaviours relate to feedback and adaptation. Behaviours (1-3) are identified by the user interacting with an aspect of the system in achieving the task, whereas Behaviours (4-6) are signified by user decision making being the dominant influence. Given that adaptations directly relate to the user Entry, transitioning to Behaviours (1-3) can be considered as positive influences to aid decision making. Alternatively transitioning to Behaviours (4-6) can be thought of as negative where user decision making or lack of action by the system results in a staggered interaction or failing the task. This now leads to the following Behaviour relations;

(1/3) indicates that the change in Behaviour is within these values, either in a positive or negative way, however, the user still achieves a "positive/smooth" interaction.

(1/3) –> (4/6) indicates that the change was between the "positive/smooth" set to "negative/staggered". This would indicate that the user incorrectly or independently interpreted the nature of the interaction.

(4/6) indicates that the Behaviour changed within these values, either in a positive or negative manner, however, the user still has a "negative/staggered" interaction relative to the system response.

(4/6) –> (1/3) indicates the Behaviour changed between "negative/staggered" to "positive/smooth". This can be considered as the system supporting user decision making, as the user transitioned from an initial poor entry condition to achieving the task in a streamlined manner.

Applying these classifications to the Altered interactions a distribution of impact can be found (Table 8-19).

	(1/3)	1/3 –> 4/6	(4/6)	4/6 –> 1/3	Total
Clustered					(27/46)
User					(4/46 = 7%)
Positive	0 = 0%	0 = 0%	0 = 0%	0 = 0%	0 = 0%
Negative		3 = 7%			3/46 = 7%
Display					(24/46 = 52%)
Positive	1 = 2%			10 = 22%	11/46 = 24%
Negative	8 = 18%	4 = 8%	1 = 2%		13/46 = 28%
Total	9 = 20%	7 = 15%	1 = 2%	10 = 22%	27/46 = 59%
Distributed					(23/46)
User					(4/46 = 9%)
Positive	0 = 0%	0 = 0%	0 = 0%	0 = 0%	0 = 0%
Negative		4 = 9%			4/46 = 9%
Display					(19/46 = 41%)
Positive	10 = 22%				10/46 = 22%
Negative	3 = 6%	6 = 13%			9/46 = 20%
Total	13 = 28%	10 = 22%	0 = 0%	0 = 0%	23/46 = 50%

Table 8-19: Showing the percentage and distribution of positive and negative influence over Altered Behaviours during interactions.

In both configurations we see that the actions of the display present the strongest negative influences in the interaction, with marked reductions both within and between each set of Behaviours (1-3) and (4-6). This is directly related to users not being able to identify meaning in the position marker, and confusion in Entry due to the delay in adaptation.

Following the previous positive and negative influences of each configuration (see above), the Clustered condition has a significant correcting or supporting role in drawing users from the user-led Behaviours, given the large gap, simple layout, and opportunity for user awareness and learning. While this configuration elicits inherent Entry and approach Behaviours seen across all studies, the delayed adaptation and relationship to the position marker become clear and support later approach and correcting actions.

With the Distributed case the large number of gaps slows the users Entry and encourages observation, so identifying adaptations and localising their awareness. The positive influences of the display are then seen in the system-led Behaviours where the user becomes aware of the position marker, so supporting their early assumptions of the interaction and meaning. This is seen to be due to the local scale of interaction, where the users is identifying a location at the display and drawing further understanding of the position marker during approach. Conversely there is no influence to the user-led states in this configuration, as any user-led action taking the user away from the local point greatly limits awareness and potential for learning around adaptation and the marker.

These two conflicting approach behaviours lead to similar learning opportunities and highlight the same issue of the system. Where user-led Behaviours lead to a local position and a later relationship between global aspects of the display, slower approach and local awareness of gaps i.e. system-led, allows for a focused interpretation of the global aspects. In both cases there is an initial lack of identification or relationship to the marker, although there are many cases of users identifying the marker appearing at Entry and having a responsive state. The transition to the leading state with no indication or additional feedback leaves users unable to clearly form meaning from the markers actions, with the delay in adaptation becoming a serious issue within the interaction.

Providing a constant responsive state would not only remove the issue of the delayed adaptation, which has been seen to be a strong attractor for approach in both configurations in the Adaptation study, but would act to support exploration, strengthen ownership, and encourage playful interactions as seen in the Responsive study.

8.3.4.1 Transitioning to and from Behaviour 1

Specifically considering examples of Behaviour 1, where users are seen to interact with the position marker in forming their interaction, we can accurately detail the factors of both display and user's behaviours within this iteration of system design.

In total 12/50 = 24% of Altered users transitioned either in or out of Behaviour 1. These are described in Table 8-20:

Total Altered interactions of user in Behaviour 1					
	Start	Final	Freq.	Influencing Factors	Total
Clustered					
Repeat-1st	1	4	1	User identifies marker – Pre-empts movement – As user gets to location begins to follow marker again	-1
	1	6	1	Jumbled adaptation – User interacts with marker – Marker begins to lead right – User moves left	-1
Repeat-2nd	3	1	1	Upon entry there is a jumbled adaptation – User waits while adaptation is confused – User engages and follows position marker	1
	4	1	3	User enter confidently towards the gap – During entry the user identify the marker and follow it to find the new window	3
Distributed					
Novice-2nd	2	1	4	Initial adaptation draws user to centre of space – Position marker is easy to engage with from user position	4
Repeat-2nd	2	1	1	User follows initial adaptation – Second adaptation - Marker moves towards new gap – User responds to marker and second gap	1
	1	6	1	Adaptation in centre – User identifies marker – Marker moves towards centre – User moves left	-1

Table 8-20: Showing all Altered interaction in to and out of Behaviours 1 between all users and across both conditions.

The strongest indications for identifying the marker are; a level of experience of the interaction leading to awareness of the marker, measured approach and identifying the marker, early identification leading to a change to confident approach.

Again this indicates that having a delay in the adaptation is detrimental to approach as there is no clear relationship to any part of the display, but further to this there is a need for greater immediate meaning from the position marker where users can identify it. This points to the responsive state being maintained and richer feedback being offered.

Where there is no clear adaptation or point of interaction, more likely in the Distributed case, the user approach is delayed. While this offers a greater opportunity to identify the marker, there is a need to make this explicit during early Entry and approach to prevent a slowed or staggered interaction. This issue is further compounded where there may be alternative adaptations taking place, or simply movement from on-going users. These actions can provide a false positive to the user at Entry and lead to complete separation form the marker. This further reinforces the need for the responsive state and richer feedback.

8.4 Outcomes of the study

This study has now considered how the presentation of feedback and adaptation relative to predicted approach both supports and influences approach and engagement for novice and repeat users. While the models of entry and the feedback shown are simplistic, this offers the most challenging conditions to highlight positive and negative aspects of the system.

With the use of feedback and delayed adaptation it was seen that 71% of users achieved either a streamlined adaptation or adaptation and position marker based approach, rising to 80% when considering all system-led interactions. For the remaining users it was found that 10% recovered the interaction through adaptation and feedback, however, the final 10% did not achieve the interaction in any form. This issue was further compounded when considering Altered interactions, where users may have engaged with the system later in the interaction, or been unable to identify meaning in the feedback or adaptation. In total 44% (35% / 80%) of users who achieved the interaction in a system-led Behaviour were the result of an Altered interactions, indicating a significant issue in the current design of feedback.

While learning played a role in identification of the marker and its meaning, the limited feedback in marker behaviour transitioning to the leading state, and the overall meaning of the leading state to the final adaptation proved to be the most significant issue for users in achieving the system-led Behaviours. This now leads to several design considerations for the role of feedback in the delayed application of adaptation.

8.4.1 Design Recommendations

Based on the findings of this study there are clear design implications in presentation of feedback around displays with a delayed predicted adaptation. These are;

Responsive interaction: A marker should be shown to users in the landing zone at Entry and remain in this state throughout. Without a clear adaptation showing a layout change, or causing movement of on-going users, there is no clear relationship between the Entry and the system defined position of adaptation. The responsive interaction works to improve the user experience in a number of ways, including; encouraging interaction with the system response, greater investigation of the interaction, playful exploration of the space and any other features of the interaction, and most importantly establishes ownership. By leaving a marker in the responsive state users maintain a connection to the display and have a focal point to consider additional feedback presented from that position, regarding movement, interaction with other users, or aspects of the space itself.

Feedback of adaptation position: A clear relationship between the position marker and adaptation position must be established for users. In this trial the marker would transition to a leading state with no clear relationship to an end point or exhibiting additional feedback to imply meaning. As the adaptation is delayed the relationship can only be found in a limited number of scenarios. Instead, a secondary factor of feedback should be presented to indicate at minimum a direction of movement, with additional factors of distance, speed, or position being optional, but potentially adding significant support in managing the interaction.

Influence of configurations: Both configurations were seen to influence factors of Entry where there was no immediate feedback presented through adaptation, as seen in the Adaptive study. The large gap associated with a Cluster led to confident approach in repeat users and complete separation from the movement of the marker, while a delayed awareness of feedback would encourage glance behaviour towards the Cluster, potentially identifying the marker. With the Distributed case the number of points of interaction and increased cognitive load required lowered awareness towards the display and marker, and the formation physically blocking line of sight and awareness during later interaction.

Defining the configuration: As seen in the Adaptation study, pre-defined configurations and intended outcomes of adaptation influenced Entry and the emergent interaction. With an awareness of both local and global influences of configuration in the identification of the position marker and awareness of adaptation, there is now a stronger case for pre-defining aspects of configurations in the space. Presenting clear landing zones, gaps, clusters and freeing points of interaction, whilst simultaneously introducing movement and leading effects may go a long way to influence the use and intended flow or movement patterns.

Identifying user types: There were clear implications for more experienced users or user expectation during Entry. Where Novice users appeared more cautious and inclined towards behaviours seen in the Responsive study, Repeat users showed greater confidence and awareness of the display. In identifying these specific actions by users during Entry it may be possible to more accurately classify users in identifying responses to feedback and adaptation, but also characterising factors of their interaction, such as dwell time, response to adaptation, and movement or flow.

8.5 Summary

This chapter has now considered how informed adaptation approaches might be applied to a display based on predicted user entry behaviour relative to the clustered and distributed configurations, and the role of feedback in supporting entry and approach while mitigating the impact to on-going interactions. The findings indicate that while a reduced level of feedback through the actions of a position marker and delayed adaptation can support new user interactions, there are multiple points of confusion around the current levels of feedback relative to the adaptations which had previously seen to be effective. The significant finding, through the observed and reported issues by users, was a need to improve the discoverability of the position marker and levels of feedback and relationship this held to the adaptation in supporting understanding and engagement. This leads to considerations for the minimum levels of feedback required in supporting users, but also the range of feedback that might be applied to introduce secondary considerations to support the intended design and use of space. This now leads to a clear minimum requirement in applying this approach, but also several areas of further investigation within the problem space.

8.6 Contribution to Knowledge

This chapter has now presented an approach to applying informed adaptations to a display as a mechanism to manage and support multiple simultaneous interactions, aiming to maximise utility while mitigating interruption to on-going interactions based on the entry behaviour of a new user. This has presented factors of on-going interactions as components of user awareness, influences in decision making and as a basis for classification in supporting the wider use of space within a specified design criteria. This study has also defined and highlighted the need for a series of design recommendations for the minimum requirement in the levels of feedback required in applying this approach to best support users. This has situated the use of adaptation as a mechanism to manage display layouts in relation to on-going use as a component of the emergent ecology and new user entry, and presents a series of areas for further investigation in multiple simultaneous user displays.

Chapter 9: Discussion

Displays create shared social spaces and focal points which influence the use of space through their situation, presentation and on-going use. User interactions with and around these points lead to observed phenomena around sharing, collaboration, co-operation, competition and breakdown in both social organisation and the interaction design, and while the emergence of these phenomena is understood, the implications within the ecology of interactions and user experience are not well related. In assessing how awareness and decision making form through entry and approach, given social and physical elements of on-going display use, a consideration of display presentation and real time adaptation has been carried out to situate the role of display behaviours as a mechanism to both support and manage multiple independent simultaneous user behaviours at a large display.

9.1 Summary of the Research Question and Assumptions

This body of work has now answered the proposed Research Question and underlying objectives;

How can people's spatial behaviour be used to dynamically lay out content on multi-user, interactive screens, and how does this dynamic layout affect people's spatial behaviours?

1) Identify and evaluate the range and impact of factors of display and interaction at surfaces in multiple user scenarios to inform issues of conflict and breakdown around use.
    a. What are the multi-user and display factors that lead to issues of conflict and breakdown with and around public displays?
    b. How can factors of use be related to layout and presentation designs to further explore the user behaviour and response?
    c. What are the roles of layout and presentation in influencing behaviour?
2) Develop a system capable of evaluating a range of layout and presentation factors during multi-user interactions to inform the use of these factors in natural behaviour.
    a. What are the minimum requirements of a system to evaluate a real world scenario?
    b. How do aspects of entry and feedback influence the natural use of an interactive display and what is the impact upon user experience?
    c. Which factors of layout adaptation can be related to approach behaviour and on-going display phenomena?
3) Ground the role of system-led adaptation as a mechanism to influence natural interaction.
    a. How are the system led adaptation approaches related to natural formations of users and user decision making?
    b. How and when are adaptation strategies appropriate, based on user experience?
    c. What are the leading factors in user decision making when considering display feedback, social interaction or adaptation?

In developing the investigation of the Research Question a series of assumptions were made around how users would observe, interact, and engage around digital displays, to support both the design of studies and analysis of the findings. This was done to reduce the complexity and variability inherent in ecological interactions and to provide validity in the interpretations required within the iterative investigation. At each stage of the investigation the assumptions were considered in the design and interpretation of the findings, with the overall implications considered later in this chapter. These assumptions were;

- User responses would be homogenised across sufficiently large groups or repetitions, so supporting the concept of quantifiable clustered responses in forms of behaviour.
- Engagement and response to various layouts and forms of digital displays would be the same relative to the physical configuration and situation, regardless of the nature of the content or interaction which is being shown.
- User awareness, understanding and response could be simplified in isolation on a per-user case across MISU interactions and applied retroactively to the defined modes of use.

Considerations of these assumptions throughout the thesis resulted in limitations in implementations and analysis of the findings, where either, the behaviour or nature of individual use was not clearly identifiable, or extraneous behaviours resulted in significant outliers impacting interpretations. These points are addressed throughout this chapter.

9.2 Summary of the Study Findings

The previous five chapters have considered observations from field work and an iterative laboratory investigation to examine the nature of MISU interactions around large interactive and adaptive displays. The findings present qualitative evidence to both corroborate previous insights and to further expand the knowledge of the field, leading to a series of recommendations around the design, implementation and on-going use of these systems, and supports the basis for a novel approach to address complex real-time interaction.

Within this work a number of longitudinal and context specific findings were identified in addressing the open-ended considerations of the design-based research question, with elements of; contextualisation, specific factors of use, design recommendations, and inherent user behaviours, all forming components of the answer to the question. While the objectives and sub-questions were all answered separately or in part throughout the chapters, the development of considerations around these points is more fully explored through the narrative of the investigation and incremental iterative changes. As such, the discussion will follow and develop upon each set of findings as presented.

9.2.1 Identifying factors of display, presentation and user behaviours

In approaching the problem space a series of observations were made of natural multi-user interactions with and around displays and digital content. This sought to compare and contrast factors of emergent social phenomena and conflict, leading to stable organisations of multiple users around a range of display paradigms to highlight potential influencing factors of digital content. This considered the first two sub-questions of objective one:

a. What are the multi-user and display factors that lead to issues of conflict and breakdown with and around public displays?
b. How can factors of use be related to layout and presentation designs to further explore the user behaviour and response?

In considering issues of conflict and breakdown the observations indicated a strong contextual correlation at all levels of interaction and organisation, with varying factors working to define the context leading to definition of boundaries.

The overarching influence in entry to a space and early approach was seen to be the situation of the display and how this influenced awareness and discoverability of points of interaction. These factors work to directly influence movement and flow patterns, with the situation and on-going use acting as a boundaries to awareness to define how conflicts might arise, where the context of the interaction is captured in the local on-going use (Anvari et al., 2013).

With the inclusion of multiple points of interaction this can be seen to introduce global context to a space, where forms and formations of use can both influence, inform and describe boundaries and movement patterns and decision making as interpretation of interactions led to generic forms of behaviours (Vizzari et al., 2013).

Interpretation of these formations can be directly influenced within the situation of a display and act in conflicting manners during entry and approach as the local context of an interaction may not be identified through functional formations alone. Instead there is consideration of ownership, presentation type, and interaction behaviours which all act to define the local context of use and so more clearly indicate boundaries (Benford et al., 1994). Where these factors are not interpreted during approach, global factors of context will define points of entry, although these may not be in-keeping with the local context and so lead to conflict and breakdown in organisations and interactions.

These forms of conflict and breakdown then lead to emergent phenomena of social organisation moving towards more stable organisations of co-orientated users, and are seen to more clearly inform the local context of use within the global scope. It is in these stable organisations of users that we can see boundary conditions "soften" and the emergence of formations. While larger formations can more clearly indicate the local context these can face similar problems of boundary conflict due to limited awareness, either through reduced display size, interpretation of interaction, or content type and situation. This raises questions of how formations influence the global context as points of attraction or stable interactions.

Deeper consideration of content presentation and forms of interaction highlights how local context is defined during approach through awareness of formations, on-going use and interaction. Transitioning through the spectrum (Chapter 4: Field Study - 4.2.3 Interaction type and the nature of user experience) of content types it appears that greater levels of interactivity shift the display from a static, socially organised interaction, to a social-digital entity, where forms of layout or presentation change are mapped to users behaviours and changes on a display exhibiting a social impact (Peltonen, et al., It's Mine, Don't Touch!: interactions at a large multi-touch display in a city centre, 2008). This can soften boundaries through interpretation and necessity, but imposes new concepts in how presentation can impose territoriality and implications to social organisation.

This gives a strong argument for consideration of user interpretation and experience relative to layout and presentation changes as informed articles of the ecology of use, as it is possible to identify spatial changes in response to a display. This does not inform the context for multiple users but instead informs how, where, when, and why layout or presentation changes are appropriate and the influences they have identifies application areas.

While the number of large digital displays and forms of interactivity were somewhat limited, the interpretation of the context of interactions supports cross considerations of users behaviours for a number of situations and the influence of digital displays. Further drawing in considerations for all forms of digital display presentation and content type as an influencing factor in boundaries supports the concept of user experience as a direct design tool in expanding and exploring the problem space, but does not present clear factors of use.

9.2.2 Isolating factors of user behaviour relative to display and presentation

While there were indications that presentation plays a strong role in approach distance, examples of this were not seen across more complex layouts, and so there were no indications of how layout and presentation would influence organisations. This resulted in boundary and conflict observations being initially related to local and global contexts of interaction. Identifying the role of presentation and layout in multi-user interactions required consideration of a Wizard-of-Oz trial to evaluate how these factors influence formations and organisation. This considered the third sub-question of objective one:

c. What are the roles of layout and presentation in influencing behaviour?

Presentation, including the size of windows and content, was seen to be critical in the formation of users groups relative to layout. This relationship of depth from the display and approximate viewing area of a formation implies a contextual ownership to aspects of the display, including multiple windows and components of changing layouts (adaptation of interaction points), within the global space (Kendon, A. 2010). While there will be a relationship to the size of a window and the presentation of content and it's type (which was partially explored), the position, formation and orientation of a group can supersede window size, but is bound by presentation in the minimum requirements to engage and co-orientate.

Identification of ownership and contextual ownership plays a significant role in spatial organisation and interpretation of points of interaction, where groups exert a significant influence over the manner of subjective interactions for those outside of the group, as opposed to groups of non-connected individuals (Deutsch & Gerard, 1955). Formations of users imply a peripheral boundary of interaction behaviour towards a layout, and exert a social relationship over entry to points of interaction captured within. Changes in interactions and co-orientation of users, and display layout at these boundaries then act to influence planning and approach for external users in supporting and maintaining stable interactions.

Interactivity and responsive layout changes, either presenting a window or adaptation, are identified by approaching users (Müller et al., 2012), this forms a basis for ownership (Fritsch, J. 2009), however, these factors can also be captured within a perceived peripheral or contextual ownership boundary which govern the potential for approach and entry (Sukale et al., 2014). This influence of local context within a display driven global (ecological) context gives significant indications that the formation of users and subsequent boundaries presents a serious point of conflict and contention in the use of these systems (Brudy et al., 2014).

The formation and co-orientation of groups, along with depth from the display, initially describes the extent these boundaries may influence areas of awareness and approach by other users. It is also the case that changes in layout inside of these boundaries will act to influence the group themselves for both positive and negative impacts (Bezerianos & Isenberg, 2012), in both capturing attention and separating co-orientation, or in supporting on-going behaviours between groups and points of conflict, extending the concept of "chained displays" (Ten Koppel et al., 2012) as an internal mechanism. This secondary point was seen to be related to a social awareness or relationship to content windows, where on-going groups can exhibit an inverse relationship to social awareness of the needs of multiple groups directly related to alternative points of interaction at and within peripheral boundaries.

In both supporting issues of social conflict and local co-orientation it is seen that groups must a have a tight coupling to any and all windows held within their interaction context (Brudy et al., 2014). This is found through the layout, presentation and ownership of these windows and the relative position and formation of the group, with adaptations and layout changes being most effective when they support expected outcomes (Jacucci, et al., 2009) and co-orientation of groups (Schiavo et al., 2013), with "after the fact" adaptations being appreciated where users are able to form an interpretation of the reason. A reduced workload and path of least resistance must be presented to a group for there to be an effective influence through changes to layout or presentation. There is a strong case for either, digital feedback or a social relationship to components of a layout to help inform understanding of an adaptation, or an understanding of social need where there are boundary conflicts in multiple user scenarios, with a preference for changes amongst familiar users improving the overall experience (Kurdyukova et al., 2011).

Limitations in these findings were found in the group composition as members were previously unknown to one another and so cohesion and co-orientated response may have suffered. It may also be the case that approach and response of these groups to factors of presentation were not accurately observed as intra-group social boundaries may have been more prominent than would have been expected, however, this results in a worst case scenario for the formation, organisation and response of users to these factors and so further highlights the importance of their relationship to changing layouts and presentation.

There were multiple components investigated within the study which were not mapped to specific on-going behaviours, meaning that no one factors can be clearly identified in its role. This does give broad indications of how these factors influence spatial behaviours but limits the criticality of impact as the factors were not tightly coupled in the design. This now suggests the roles these factors play in on-going use and what not to do in these scenarios, but also indicates further crucial areas of investigation. Instead, the findings point towards the importance of dynamic boundary creation in multiple user scenarios and considerations of the influence of local formations and boundary interactions leading to conflict, where factors of responsive mapping and feedback can inform the global context of use.

These sections have now answered the sub-questions of objective one.

9.2.3 Development of the scalable system

In further exploring the interactions of multiple users around changing layouts of displays a fully working test system was created. This drew in findings from literature to support the design of a user interaction expanding upon concepts identified in the earlier field work and lab based studies to explore concepts of situation, ownership, peripheral awareness, and emergent user formations in on-going use and entry.

Development of the system presented novel problem areas and involved solutions leading to a technical contribution in the use of multiple depth cameras across a single reference frame. This meets the need for a situationally appropriate (Marquardt & Greenberg, 2012) (Shoemaker & Booth, Whole-Body Interactions For Very Large Wall Displays, 2008) iterative test-bed system previously identified (Kühn et al., 2011).

This section has now answered sub-question one of objective two.

9.2.4 Influences of situation in emergent phenomena leading to social organisations

Exploring the implications of the earlier findings within the working system, the situation of the display and relative peripheral interaction of content windows formed the two key variables of the study. This explored how mapping of content would influenced ownership, awareness, and learning, leading to, and within, on-going emergent formations.

Critically it was seen that experience of the interaction and system function supported natural mitigation of emergent phenomena identified as sources of boundaries and conflict in multi-user interaction at shared points of use. This saw users naturally distributing across the display due to both learning and awareness of spatial organisation and system behaviour. This form of learned behaviour acted to mitigate social boundary interaction and maximise the display utility for MISU interactions where no implicit information or feedback was given.

Awareness of formations and layout of the display were seen to be the strongest factors for applied learning and identifying approach and engagement. Each entry conditions related to situation influenced awareness, and more importantly the context of learned behaviour. Where perpendicular entry encourages a wider awareness of the display and on-going use due to the improved visibility catchment area (Xie, et al., 2007), there was also improved investigation through (two) edges, due to naturally centralised approach, helping to situate learned behaviours as explorative (Luff, et al., 2003). The corollary of this was parallel entry, where dense clustering and honey-pots (Hornecker et al., 2007) propagate to enforce "lock-in" and "grid-lock", minimising awareness and exploration of the display, promoting a competitive learned interaction and limited global interpretation.

While clustering is seen in both cases it is a persistent feature of the parallel condition, with the perpendicular case being more naturally suited to self-organisation (Akpan et al., 2013). With influences of parallel situation to; route planning, awareness, and levels of effort and exploration limiting opportunities for landing (Müller et al., 2012), and enforced clustering with lower awareness of interaction behaviours encouraging clusters in more distributed cases (Marshall et al., 2011). This impact was seen to be mitigated where users experienced a wider sense of learning around the nature of the interaction via perpendicular entry.

This leads to considerations for how natural organisations and situation can support natural learning and feedback to orientate users to a global consideration of space and boundary interactions. There are limitations in the comparison as each group was shown both conditions, however, the observed behaviours, reported interpretations and changes in behaviours between each trial indicate the initial divergence and interpretation given situation. With wider awareness and learned interactions being supported through enhanced feedback or system-led adaptations, applied "learned" effective organisations would act as an approach to mitigation and improved utility.

9.2.4.1 Clustering and the emergence of social phenomena

While clustering is a natural organisation through a number of factors, this was also a significant point of conflict in emergent interactions. Through considerations of factors of clustering in both configurations and the relation situation had to awareness, learning and feedback a series of approaches to mitigating clustering were identified.

Clusters were seen to emerge through the minimum requirements of users towards a point of interaction during entry (Hornecker et al., 2007). This includes distance travelled, line of sight, and minimising the impact to on-going use, where impacting upon an on-going experience is seen as a negative component to be reduced (Coutrix, et al., 2011), however, this is both subjective and related to the context of interaction. Emergent formations and phenomena are seen to be enforced in given clustering and contextual organisations, where achieving an interaction supersedes social organisation and boundaries.

Where configurations become enforced given the organisation we see emergent phenomena as the context becomes locked-in within the on-going interaction due to lack of environmental influence or feedback. This further propagates the effects and leads to softening of boundaries in avoidance of conflict. These boundaries then lead to discrete points of interaction each with their own context of use to define the global context.

The emergence of clusters and locked-in effects leads to a two part consideration of learning as users are exposed to differing interpretations of the mapping and window interaction based on the number of users, number of visible windows and context of the interaction (Reeves et al., 2005). With early entry or areas of limited use (landing zones) allowing exploration of the mapping and interaction to inform use, and later entry or large numbers of users (areas of higher density) restricting the exploration and instead relating the window interactions to competitive territoriality towards a stable local organisation (Benford, S. 2010) (Peltonen, et al., 2008). Within clusters, this reduces the awareness of window interaction and global exploration, promoting clustering as the main interaction modality in later trials.

Of the two configurations perpendicular entry more readily supports awareness and exploration of the space, and the movement and interactions of experienced users are more quickly identified and related to global potential of the system in achieving a window. In parallel entry the initial landing zone and competitive learning tendencies see continued clustering and the actions of experienced users become less pronounced.

With early entry in both conditions, mapping of content gives a strong sense of ownership and reinforces interpretation of the interaction within honey-pots and clusters. Users who experience this mapping and ownership experience a much greater adverse effect to the context of the interaction due to social pressures and lock-in, as the point of interaction requires shared stable content and ownership is lost (Brudy et al., 2014).

These forms of learning directly influence later entry and approach, with identification of the mapping encouraging exploration (within both contexts of situation), experience of lost window ownership encouraging avoidance of “popular” areas and clusters, and an awareness of window interaction encouraging testing and exploration around clusters and gaps (“wedging-in”). Each behaviour is seen to alter entry in some way, however, both lost window ownership and testing of entry to clusters are seen to have a negative influence due to social-digital boundary conflicts. The first of these points is a strong adverse effect, while the second (seen in less experienced users) is not a critical issue as it is a component of investigation, however, there are considerations for mechanisms to avoid this.

Of each learning case there is not a need for direct knowledge of the mapping or interaction to influence behaviour, instead an approximate understanding will support local organisations and help mitigate emergent social phenomena. This said, knowledge and experience of the mapping presented the strongest connection to the display and awareness of actions and behaviours within global decision making (Shoemaker et al., 2010).

While these findings indicate a strong influence from learning, findings were inferred from observations and user reporting and do not directly consider how users may have achieved learning or awareness or its contextual meaning. The concepts found were derived from observed changes in overall behaviour and reported decision making, where consideration of a single user across all trials may have presented a stronger relationship with forms of feedback and influences of situation and social organisations.

Clusters were seen to be emergent organisations of users, so situating the role of presentation and layout with natural social phenomena. While this gives broad considerations for how these factors interact, the resultant formation of clusters were loosely coupled to aspects of the display, and so direct relationships of formation to entry and approach cannot be directly found. Instead the loose formations and emergent organisations indicate the minimum levels of mapping and feedback in learning within use.

9.2.4.2 The role of feedback to influence emergent phenomena

The role of feedback was seen to play a significant role in mitigation of social phenomena and supporting learning. Where there had been examples of local clustering still emerging after two system interactions, giving the basis for influences due to learning described above, the inclusion of feedback showing window interactions rapidly improved issues of localised clustering and learning towards distribution.

Improved learning through feedback resulted altered behaviours during both approach and on-going use, where previous clustering behaviours were quickly identified, and (novice) users transitioning towards more experienced distribution behaviours seen by those who had previously identified the mapping of content encouraging exploration. This suggests that feedback improves not only local organisations but indicates the wider context of interaction and use through reinforcing constant experience of the mapping and need for separation.

With constant responsive feedback ownership was greatly reinforced and awareness of the potential interaction context better supported at entry. While novice users were initially guided by factors of the underlying situation and on-going organisation, more experienced users identified the mapping and feedback to achieve alternative approaches towards potential points of interaction, leading to greater initial distribution allowing for easier interaction, interpretation, and correcting behaviours from clusters (Rodden, T. 1996).

Interaction between windows presented a visible periphery of ownership and digital awareness about points of interaction. While the feedback did not clearly exhibit the meaning of the interaction i.e. depth of an approaching user, the peripheral boundary was then interpreted via experience (Huang & Mynatt, 2003). Novice users would glance around the space in identifying a social relationship to windows, informing the relationship between feedback and social boundaries (Brudy et al., 2014). While this impacted upon their on-going experience by breaking focus to the mapping and ownership (Walter et al., 2015), this reinforced the interaction context leading to digital awareness.

More experienced users more readily identified the digital relationship and interpreted meaning from the digital awareness, relating this to the context of on-going use. With sufficient space in the direction of movement of an approaching window there was little need to respond, however, in denser situations these users would move away from points of unstable window interaction i.e. identifying a user was trying to approach and there was insufficient space. This in-band feedback, while not clearly designed, had the effect of greater distribution while simultaneously supporting local organisation, and the development of local stable groups of windows within the wider distribution. This suggests a need for feedback to more clearly identify the social-window relationship between users allowing trust and focus to be maintained (Jacucci, et al., 2010).

While both responses tend towards distribution of clusters there can also be a tendency for users to “over-respond” to these interactions, this results in significant distribution between users, with gaps forming (not always sufficient to support a new window) and an overall poor formation across the display. Coupled with natural approach behaviours due to situation giving further localised clustering, these gaps then draw approach as entry points.

During approach digital awareness was seen to have an applied impact to the display. While the feedback design does not indicate depth, on-going action or intent, persistent presentation of a window gives an implied need to a location which is interpreted in different ways (Bradel et al., 2013). Adjustment around these locations leads to “wedging in”, where the approaching user forces the interaction, indicating a social pressure to an on-going interaction. While this was an applied tactic, the implications to on-going use are generally not appreciated by either party (Benyon, D. 2012).

Where wedging in is seen, adjustment and distribution eventually reach the “outer bounds” of a distributed cluster of windows and edges of the cluster or edge effects of the display will represent local context for interpretation and interaction. Where the internal structure no longer supports additional approach (although gaps may exist) the cluster will result in “grid-lock”, where no amount of internal adjustment can support an additional window and the need for social organisation becomes lost in response to the organisation of windows (Marquardt et al., 2012). The bounds of the cluster are then required to move to support this approach behaviour, either through propagation of the interaction, or global intervention.

While feedback was limited to only show lateral position, greater indication of depth may have better supported local interpretation and learning, and related the display feedback towards a global consideration of behaviours, so influencing the effects seen (Ledo et al., 2013). Further, feedback was shown through altering the window directly, and not as an external component to the user-window relationship. This led many users to initially consider the feedback as related to their actions or behaviours and an expected response which they could not identify. Presenting inter-user relationship outside of the bounds of the window may also have better supported a global interpretation of window interactions.

9.2.4.3 Spatial influences of display feedback

Investigation of the mapping and exaggerated movements led to greater contextual ownership to locations at the display, occupying significantly more space than required to show a stable window. Components of the display, namely edges, were seen to reinforce this behaviour, lending a territoriality to user position and space (Peltonen, et al., It's Mine, Don't Touch!: interactions at a large multi-touch display in a city centre, 2008), encouraging users to be less inclined to move towards edges during window interaction.

Edges and ends of clusters (virtual edges) acted as fixed boundaries or anchor points around local organisations (Star, S. L. 1998). Users within these boundaries were unable to adjust sufficiently as their behaviours and need for adjustment would not be effectively transmitted between users towards these locations. With larger numbers of users between these edges the overall spatial use internally would be reduced, so affecting utility of the display in supporting additional approach and larger numbers. Further, the implied context of multiple adjusting users indicates unstable organisations which are avoided. This context then extends past the edges of formations and results in wider distribution and reduced usability.

Indicating user-user interactions through window feedback implies meaning to the actions and behaviours of the user themselves and not to the interaction, leading to a fundamental breakdown in interpretation (Dix, A. 1994). This leads to confusion and retreat to stabilise the interaction. While users are attempting to correct window interactions laterally (possibly due to approach), stepping back confuses the formation and makes further approach and organisation more challenging, again reducing usability.

This section has now answered sub-questions one and two of objective two.

9.2.5 Application of adaptation strategies

Having identified the issues around situation and influences of feedback in emergent behaviours towards a distributed MISU scenario, the investigation considered how adaptations modelled after approach behaviours of experienced users could support novice users. This sought to identify how “targeted” and “continuous” adaptation strategies of content windows were perceived relative to clustered and distributed use in achieving a stable distributed configuration. This explores the first two sub-questions of objective three:

a. How are the system led adaptation approaches related to natural formations of users and user decision making?
b. How and when are adaptation strategies appropriate, based on user experience?

Both strategies were found to have positive and negative influences to approach which alter their effectiveness in drawing attention, supporting new engagement, and maintaining user experience. For optimal use these strategies should be used in conjunction.

During entry aspects of formations exhibit both attractive and repulsive influences to early decision making, leading to confidence or “locked-in” decision making during approach (Ballerini, et al., 2008), this can lead to false positives or missed opportunities for awareness, where there is insufficient global information or inability to correct based on layout changes or feedback. Further, aspects of local organisations can contextualise wider expectations of the system and user experience, where tight-knit formations can indicate limits of possible interactions, and limited gaps within distributed formations being seen as “unfair”, where presenting local deviations in context for points of entry is not seen as a positive factor.

As the context of the wider formation builds, through awareness of local structures, there is a requirements of a system to alter the levels of feedback presented and potential application of bulk strategies to support overall use i.e. tight-knit clusters vs. loose formations of unequal distribution. Users should not be expected to, or feel that they have applied social pressures where an adaptation has not well supported their approach given their position relative to local/global contexts.

9.2.5.1 Contextualised factors of adaptation

Expanding upon the contextualisation of local formations it is unclear if knowledge of a supporting system or the influences of adaptation i.e. creating a tight-knit cluster, change the nature of interpretation during entry. Tight-knit clusters were seen to no longer act as significant attractors (honey-pots) during entry, with novice users not being fully sure of approach, clusters were largely ignored in entry as a system defined zone of use (Fischer & Hornecker, 2012) until a global aspect changed and feedback was shown. This is not to say there was no approach to clusters, however, this was generally delayed while users explored the space, with an "expectation" of some global or system-led element (O'Connor et al., 2005). This relationship between the physical formation and expectation of system behaviour was not explored here, but does present an interesting concept.

This behaviour is characterised as group separation, or implied separation leading to enforced boundaries (Greenberg, S. 2011) (potentially due to knowledge of an interactive system or result of adapted formation), where approaching users will identify themselves as separate entities if either of these conditions are met. However, without any environmental change or feedback these boundaries will eventually become obsolete i.e. Honey-pots become reinstated and closed boundaries (Rehm et al., 2005) present the only option to join.

As with feedback, local adaptations have a knock-on effect leading to over movement or moving away, either through impact of peripheral awareness or avoidance of instability. This can affect the overall formation and usability as contextual ownership exceeds peripheral boundaries for window interactions, which were shown to support a stable distributed state.

This leads to considerations of local organisations as separate entities for limiting local window interaction and external feedback. Once users are situated at the display there is no need for local or global feedback unless an action is required, as implications of local changes leads to reduced usability and potential changes to the global context for approach. This gives rise to considerations for how known formations of users will present a global influence and the degree to which this extends past the peripheral boundary of the formation.

This concept is extended when considering the extent of peripheral influences and awareness above these locations (Freedman, E. G. 2008) i.e. responsive mapping and movement of position markers, as this was seen to have a leading effect as a secondary consideration of over movement. While this only influence users who were already moving there are considerations for peripheral factors and feedback design, such as small fast moving markers vs. bulk movement or trails to represent movement paths shown at the top of the display.

9.2.5.2 Implications of adaptation in multi-users interactions

Adaptation has several significant implications in both supporting approaching and maintaining on-going experience, however, adaptations do not supersede on-going behaviours, formations or movement in space. Users are only able to respond to aspects of physical-social space, where layout presents an additional digital-social component, such that users will pay little mind to multiple or large layout changes as they are likely unrelated to them. If new users are unable to identify a reference point or form context of a large adaptation which is not being (physically) followed they will default towards finding a stable location, whether this is in-keeping with the meaning of the adaptation or not.

In the case of bulk movement (continuous adaptation) the response is tightly coupled with the initial formation, where situated clusters do not respond well as internal interpretation and organisation are difficult to achieve in finding consensus before a group response is seen (Faria et al., 2010). Distributed users are easier to influence as they have greater awareness of the display and the actions of individuals in beginning to respond, so more readily forming an in-group mentality (Elfenbein & Ambady, 2002). These formations are less spatially coupled so reducing social impact to movement (Beyer et al., 2014). This gives rise to the concept of "coupled inertia" of formations and the likely forms of response to adaptations given initial organisation.

While relatively quick movement i.e. approximate walking speed, encouraged a level of response, the relationship of this to the formation and internal mechanisms of decision making separated users from their windows, where incremental or piecemeal changes may be more effective in eliciting a response, although this will have a lower bound (Alt et al., 2015). It is unclear how a large co-orientated group may respond to a single large window and the influence of window size and movement relative to groups, with clustered and distributed users interpreting themselves as pseudo-groups after being subjected to multiple continuous adaptations, as the corollary of group separation identified in entry around clusters.

Again edge effects are seen to play a strong role in response behaviour, where display edges act to anchor users, and slow moving end users (edges) of clusters act to "speed bump" response of those within the formation. This leads to a "hop over" effect in entry where bulk adaptations and responses cannot be contextualised, with the final layout not matching the formations and so approach moves towards the adapted stable windows of on-going users.

In scenarios of slow response or "speed bumps" on-going users will attempt recovery after adaptation. While movement or response to adaptation helps support this, the "hop over" effect quickly breaks down these efforts as approaching users assume contextual ownership of locations on the display, which can include multiple windows. With uncertainty around meaning of adaptation (due to distance and awareness) and ownership, on-going users exhibit "display blindness" towards further areas of the display and potential meaning (Müller, et al., 2009) and loose trust in the interaction (Kray et al., 2005), making assumptions about window-user relationships at locations outside of their peripheral and local awareness, with any window being shown outside of their location assumed to be in use.

As aspects of the global space change relative to adaptation i.e. hop over etc., the issue of failed response to adaptation then becomes terminal where on-going user exhibit "conscious decoupling" from the adaptation in an attempt to recover any possible interaction. This act can be compounded by local awareness of known factors of interactivity, namely responsive interactions, where presentation of a responsive window in a location of confusion can act as an attractor for separated users. This effect was seen in the Wizard-of-Oz trials where an on-going perceived ownership of space is reinforced by the peripheral presentation of new content, such that the content must belong to them. This acts to contradict the meaning of the bulk adaptation by presenting a new action.

In cases of breakdown, interactivity and responsiveness are seen to be the strongest mechanisms for identifying positions to approach. While stable locations were valuable to experience some form of interaction, users with an awareness and experience of the potential interaction sought to reconnect with the tracking and identified ownership, ultimately preventing intended approach, with novice users not gaining an awareness of the interaction and instead approaching static locations.

Identification of a responsive point of interactivity went on to have a strong local effect to on-going use when adaptation had failed. While local users had remained anchored due to edge effects or by speed bumps, multiple on-going users (two or three of the starting four) would take turns attempting to achieve a new responsive window, with several later approaching users being captured by the co-orientation and responsive interaction, creating a clustering effect. This presents a significant shortcoming in creating landing areas via bulk adaptation given anchoring effects and the peripheral capture of the responsive state.

While initial response to bulk adaptations is poor iterative adaptations become more effective and have a more pronounced effect, giving a contextual implication for on-going use and acting to inform entry. Where bulk adaptation can be seen to inform on-going users of expected flow (Gilroy et al., 2009) or movement patterns, there is a need for a landing zone or reference point for this to extend to new users. Where there is not a clear relationship of response formation to adaptation we see default approach behaviour towards stable locations and "hopping over" and a breakdown in on-going use (Sawhney et al., 2001).

The relationship of timing of bulk adaptations to available landing zones or reference points is critical in application as they can have strong negative influences in entry and impact to on-going users (Dix, A. 1994). Where bulk adaptation takes place in higher density scenarios i.e. clearing a landing zone, the movement of users can act as a leading effect drawing approach away from the approach position. While it is a beneficial mechanism to contextualise future behaviour, the immediate impact can out-weight the effectiveness of application.

Bulk movement offers a valuable mechanism for re-organisation of space and moves users towards locations for stable formations and wider on-going use, allowing for; responsive mapping during on-going use, opening landing zones, clear avenues for feedback, and offering interpretation of spatial movements, although there are considerations for the levels of digital interference in the overall social experience (Bedwell & Koleva, 2007).

There are secondary considerations of extended user experience (which was not directly considered) as local formations breakup leaving isolated users. While there are considerations of the wider context, isolated users are thrust in to the performer role which applies subjective social pressures. Through the observations, as trials ended and users retreated, this created a "leaving effect", with several individuals remaining at the display as the majority of parallel users left. While this may have been a result of the short lived nature of the study designs, these individuals exhibited no particular inhibition to remaining and to continue engaging with the content, however, overall social pressures did eventually lead to retreat before completion. In these instances, a pre-emptive clustering of errant users may have a socially reinforcing effect to support continued use, providing a "wood for the trees" mentality, or smaller more comfortable situation (Huang et al., 2008) whilst simultaneously supporting utility. Within these secondary or tertiary application contexts of adaptation, consideration of the sub-textual reasoning and boundary relationship may alter, such that the purely utilitarian result of adaptation does not best support later on-going use.

Targeted adaptation was seen to work extremely well to influence entry and approach, with clear implications of feedback (Müller et al., 2012) and minimal impact to on-going use. Limitations occur where formations do not allow for sufficient awareness of feedback or illicit a significant physical-social response, and so considerations of prior bulk adaptations may better support the space to allow targeted adaptations to be more effective. It may also be the case that greater levels of feedback would work where bulk strategies are not possible.

There is an issue with the use of targeted adaptation when presenting a new window without sufficient feedback to on-going users making the experience system-led as they are "pushed aside" before any social-window relationship or digital awareness of an approaching user has been established. While altering the feedback to make the experience more gradual or give indications of a window-social relationship, which strongly reinforces the implications of an approaching user, any reduction in feedback may then adversely affect the discoverability of the window and so render the adaptation and its impact redundant.

Throughout these trials it was unclear if users were responding specifically to local formations, adaptations, or influences of the study and interaction design. There are clear indications for each having an impact, but to what degree cannot be clearly identified from user response. As no one part of the design is prominently targeted or featured in the introduction or design, the observed and reported outcomes would suggest that all factors work in unison in their most simplified manners.

As bulk adaptations were shown upon entry it is unclear if adaptation influenced decision making outside of on-going user movement, or where feedback may be better presented to influence initial entry and approach. While the design of the study implemented the minimum levels of display feedback, there were still influences and indications of where this minimum level was insufficient in supporting users, however, further consideration of feedback mechanisms and timing of adaptations may improve the overall effectiveness for these MISU scenarios, which has not been identified here.

9.2.5.3 Implications of design and user experience

As user experience is a defining factor within the interaction there are several components of the design which negatively influence the usability and so response to the system, informing iterative development and future use.

As the system was initially responsive, any loss of this interaction or implied tracking impacts upon the experience as the lack of clear feedback or meaning makes the interaction entirely system-led. While this could be considered playful in lower density scenarios, the high pressure scenario of multiple users and un-informed adaptation makes the experience challenging. Issues of timing and bulk movement outside of on-going behaviours, group organisation, and lack of social relationship to new windows leaves users completely separated from their interpretations of an initial stable configurations.

As context forms around new organisations and a relationship between adaptations and digital awareness becomes apparent the general principle is accepted and users are able to enjoy the experience. While the need for retro-active learning and inferred window-social relationships is detrimental to both the response and experience, and would be far better supported through longitudinal approaches via feedback and a contextual application of adaptation, small system-led adaptations within responsive interactions may actually work to improve the experience, even in high density scenarios, as long as tracking and the responsive interaction are not significantly impacted.

Within the feedback approach ownership is seen to influence the interpretation of meaning, with changes to the window itself being related to actions or requirements of the user. Changes in size and “flashing” were thought to indicate either movement or timing of content, and so introduced additional pressures to users. As external or peripheral changes were seen to influence on-going behaviours, applying feedback to an external component of a window would provide richer context to the meaning, giving greater trust (Kray et al., 2005) in delivery of feedback and the response to adaptation.

This is further seen in presenting a new window with no additional feedback to an on-going user, where the window is fully formed and portrays no information to those at the display, instead only indicating an approach position. While there is a need to convey information to an approaching user, there are multiple mechanisms which could be considered. For those at the display there is very little need to provide feedback unless there is likely to be a boundary interaction i.e. high density scenarios. The most significant requirement is to convey the window-social relationship without creating a distraction.

Importantly, users must not be distracted from their interaction, either through peripheral changes or in having to identify a window-social relationship through learning and glance behaviour. Distractions to an interaction puts pressure on the ownership of a window as there is a knowledge of potential change to presentation or adaptation of a window which is not clearly understood, and so trust in system behaviour is tenuous. This could be supported through better understood feedback mechanisms.

It is also critical to consider the types of content being shown and forms of adaptation or layout changes which influence the experience. With content being shown on a timer (dynamic) and no indication of when content will change or been paused, there is a significant pressure introduced by any change in layout or local formations. These uncertainties were seen to cause retreat which further influences the formation. While static or interactive content place the locus of control with the user, and so better support a less pressured need to respond to adaptation, dynamic content would require additional feedback if layout adaptations were to take place.

Issues of pressure imposed on users due to presentation and lack of feedback resulted in retreat and had a significant impact on response behaviour, meaning configurations were not strictly adhered to, influencing entry and approach. In identifying how limited feedback and pressures of content type might better support overall usability, the interaction design did not consider this within these studies. Instead this presents areas of further investigation, both within the application of adaptations and concepts for on-going user experience.

These sections have now answered sub-questions one and two of objective three.

9.2.6 The role of informed adaptation and feedback

The final consideration for supporting entry and on-going interactions looked at predicting an approach position and providing feedback to support a delayed adaptation of the display. In delaying adaptation this considers how minimum levels of feedback can support entry and approach while minimising the impact to on-going use. This now considers the final sub-question of objective three:

c. What are the leading factors in user decision making when considering display feedback, social interaction or adaptation?

Both clustered and distributed users influence entry and awareness in the parallel entry condition in different ways. The time delay and complexity of formation will initially encourage greater awareness of the display as new users seek some form of relationship, however, where feedback is not sufficient there is an issue of Honey-pots and user decision making drawing users away from potential feedback offered by the adaptation.

Issues of formations within entry can see users being negatively reinforced in assumptions and awareness, leading to potential for breakdown in predicted approach. While feedback and adaptation still support correction and recovery in-line with entry and approach, the influences of formation and reduced feedback can create a specific problem area.

Dense clusters are initially avoided, with large gaps acting as natural approach positions, however, clusters will also act to reduce awareness towards these locations. While markers can still be identified, there is a need for a relationship between the gap and movement of the marker to be found. This can either be in slower entry and approach, or during recovery, giving an initial bias due to the formation, changing decision making and missed adaptation.

With feedback only shown via the position marker the transition to the "leading effect" removes the responsive relationship to the display, with no clear reference point to their current behaviours and feedback, so creating a distanced engagement but a disconnect in meaning (Schmidt et al., 2013). While this presentation has a direct relationship to the user, the disconnect presents a new component to the space and potential to influence other users.

Of all users entering the clustered configuration 76% were following aspects of the system through slower entry in identifying the marker, with a further 24% being directly influenced by the gap showing confident and direct approach. Of those entering with some awareness of the marker 20% were seen to revert to user-led decision making, either exploring the space or engaging with the cluster. Limited feedback and delayed adaptation see this group transition to searching behaviours and influences of the honey-pot within 3-5 seconds of entry, as there is no clear relationship between actions of the marker or global change.

The distributed configuration significantly reduces awareness of the marker as there are too many factors to consider during entry. Where user decision making or incorrect adaptation occur serendipitous discovery and recovery become much more challenging as awareness of the display due to the distributed formation is much lower.

With reduced awareness entry is considerably slower, with significant reduction in confident entry and approach. This leaves 76% of users identifying aspects of the system including the marker and 24% being entirely user-led in exploration, however, interpretation of system meaning is greatly reduced. Initial slower entry supports discovery of the marker, however, the equally slow response time within the complex formation leads many users to fail in identifying further meaning and transitioning to searching behaviour or direct approach. The number of users accidentally discovering the adaptation or having to correct is then greatly increased after initially identifying the marker.

With minimum feedback and delayed adaptation, 80% of users are seen to identify or follow the marker at some point in approach before achieving a window, 3% draw meaning from the space and exhibit confident assertions about the future adaptation, 7% correct their approach after the adaptation has taken place, and 10% of users are seen to fail in achieving an individual window. While overconfident approach and recovery result in achieving a window, actions of the display act to influence the space in ways that had not been accounted for, either in boundary interactions of on-going users or informing later entry through actions, and so these forms of behaviour must be accounted for.

Confident entry greatly reduces opportunities to present a marker and ability to inform or influence the user, where factors of formation and spatial behaviours i.e. movement, can further influence approach away from landing zones. In these scenarios there must be some consideration of how a system can pre-empt or better support approach and recovery in-line with approach behaviour (Cheung, V. 2016) and the impact this may have within on-going use.

Applying adaptations in-line with initial entry is not an effective mechanisms where feedback is not sufficient to support approach. While appearance of a window may capture attention or suggest a change due to a local social response, this does not guarantee recovery and will impact upon on-going experience. Where these changes take place there are considerations of how formation may influence awareness to the location, and factors of uncertainty around any movement behaviour that cannot be clearly related, this can act to discourage interest at these location and further propagate the issue of recovery.

While landing areas present a strong chance at recovery there are considerations for how approaching users are orientated or their forms of search behaviour. While local formations can discourage approach, without clear feedback formations act to focus attention reducing wider awareness, making adaptation and recovery challenging. This seen further with distributed formations inherently blocking line-of-sight and wider awareness as users approach the display directly.

This case presents a strong indication that a responsive position marker would offer an optimal basis for presentation of further feedback for co-ordination towards points of interaction (Shoemaker et al., 2010). Initial interaction with the marker encourages ownership and reinforces a relationship for external feedback to be shown. Any additional information would have a direct relationship to the users and their actions in context.

With the new form of system interaction users may be inclined to slow during entry and discovery, however, this should not be required in interpretation and achieving a new window. While limited feedback does support entry, there is a need for additional contextual information to be shown in supporting approach, with limits to allow user exploration without making the experience entirely system-led to ensure an enjoyable experience. These considerations must also be applied to confident entry in quickly supporting user approach and conveying information for contextually required actions to be understood.

In identifying actions of users in approach relative to awareness (Brignull & Rogers, 2003) we can identify the levels of feedback required, either through a position marker or more extreme forms of adaptation. By limiting levels of feedback this prevents overpopulating the display which could lead to knock on effects, but also maintains a user centred interaction instead of being system-led or enforced. Relating actions to a need for information; "playful" = limited, "following" = landing zone, "lost" = recovery, would best support MISU interactions.

Importantly we must consider how the minimum level of feedback can be provided to achieve a stable configuration and approach, and when this should be shown in relation to entry and approach behaviours.

These sections have now answered sub-question three of objective three.

9.3 Assumptions of the work and their impact upon findings

There were three main assumptions around behaviours that were considered within this body of work, these were;

- User responses would be homogenised across sufficiently large groups or repetitions, so supporting the concept of pre-determined responses in quantifiable models of behaviour.
- Engagement and response to various layouts and forms of digital displays would be the same regardless of the nature of the content or interaction.
- User awareness, understanding and response could be simplified to be determined in isolation across MISU interactions and applied retroactively to the defined models of use.

These factors applied with varying degrees of impact across the various studies, given the nature of the design and implementation with the general impact being described as follows.

9.3.1 Homogenised response

Where considering natural behaviours in public settings there were insufficient forms of situated technologies to establish how changes to the form of the interactions influenced observed behaviours. General underlying behaviours and literature could inform towards critical aspects of interactions in the majority of examples, however, the influence of presentation and adaptation could only be established in MISU interactions in the subsequent studies. While these studies were comprehensive in the breadth of factors and number of users considered, there were clear indications that users would be influenced by a wide variety of factors which may or may not be linked, or present consistent findings.

In response a series of simplifications were made in the design to account for the majority of the reported influences, such that a wide range of factors were represented as simple aspects of the system function. In turn, user experience was then used to identify interpretations of users understanding and interactions with these elements to consider their use in specific scenarios. This reversal of considerations presented a concise response and understanding to the use of design features and focussed the discussion of factors instead of requiring a homogenised interpretation of the ecology of factors simultaneously.

In each case the resulting interactions of users did not have a large enough user base to support homogenised behaviours, however, through simplifications leading to a focussed consideration it was sufficient to present the range of themes and Behaviours as underlying information towards models of interaction and engagement at each successive iteration. This factor was further encapsulated by the following assumption of observation.

9.3.2 Forms of engagement

Based upon the concept of homogenised interaction behaviours, it was assumed that users would ultimately engage in the same manner with the system regardless of the nature of the content mapping and presentation. This considers the spectrum of content presentation, such that, responsive, adaptive and predictive content mappings would illicit the same nature of response behaviours for a homogenous group of users. This assumption came from considerations of literature and the field work, where users were seen to form their interaction behaviours based upon the same factors regardless of the system type, and were only influenced by specific factors of any single type of system after their initial engagement.

Secondary factors were found as the initial assumption of homogeneity had to be refactored within the design. Instead of being able to actively test the assumption of engagement with all forms of the system, a number of simplifications were made to directly target critical factors of display use. While these simplifications followed the concept of uniform engagement behaviour, there were wide ranging examples of discrete user behaviours identified with the adaptive and predictive systems. Within this, ranges of behaviours were identified as having a number of modes, and so while not uniform, there were indications that behaviours could be categorised within the initial expectations of this assumption.

While it was found that this assumption was too generic across all forms of engagement, with varying aspects of the system design and implementation, there are indications that specific aspects of the design could be presented to support uniform behaviour with additional testing. Considering how adaptation and feedback could be used relative to specific aspects of formation and user experience to create a more informed understanding of display layout changes.

The implications of this assumption leads to the final considerations of assumed behaviours.

9.3.3 Identifying individual behaviours

Initially this assumption appears at odds with the nature of the previous two, with aspects of individuality being identified within a homogenous understanding of interaction, however, this final assumption carried two specific aspects in understanding and classifying behaviours. The first being; that if behaviours were homogenous and consistent throughout all forms of interaction they could be readily identified. This is ruled out by the previous discussion of the first two assumptions as there were found to be wide ranging modes of behaviour, along with inconsistencies within the relationship of these behaviours to aspects of the display presentation. Instead, simplifications in the design and implementation of factors were made within the observations, leading to clear distinctions in individual behaviour being possible compared with the design.

The second consideration; that individual behaviours could be identified and related to models of interaction. Instead what was seen was wide ranging number of individual factors quickly confused the nature of models of interaction as user experience was considered as a critical component in interpreting mapping of content changes and adaptation to on-going formations. Subsequent simplifications to the modes of interaction and removal of user experience as a guiding factor supported the concept of individual behaviours being identifiable within study four and considerations of prediction. By only addressing a number of influencing factors and changes in mode of behaviours gave a more appropriate response, leading to a greater understanding surrounding concepts of individually identifies models, allowing experience to inform aspects of the implementation.

With individual behaviours can be identified, there is an overarching requirement for the modes of behaviour and models of interactions to initially be simplified until there is richer data to support the concept and matching process. While this assumption was found to be viable, it was not carried throughout the work and suffered being captured between the needs to maintain integrity of the prior assumptions. Instead, it is likely the best option that these three assumptions of behaviour are considered independently and finally in unison to address the most effective design approaches to this system.

9.4 Implications of the findings

This body of work has now presented a wide ranging number of factors relating to MISU interactions with PLID's for a variety of forms of presentation and interaction modalities. Each study has considered a number of components of MISU interactions within an ecology of engagement behaviours, ranging from social and physical factors to design and real time feedback. While the findings are not as robust as a more focussed study, the ultimate mechanism and supporting understanding found in this thesis paves the way for the situation of future works in all aspects of MISU interaction.

Considering how each form of interaction is related to wider factors of space, behaviour, interaction, engagement and user experience, we can assess the levels of impact seen within each of these spheres and incorporate this understanding back in to the interpretation as part of a closed loop system. By closing the loop in this manner, any issues identified at the translation between the design and implementation phases can be accounted for in real time through a variety of mechanisms, ranging from models of interaction to support on-going user experience, or via direct rule based implementations to address the requirements or flow of the space, lending itself more towards adaptive architecture.

While classic approaches to interaction and engagement have identified the ecology of interaction, the supporting technologies have not been available or entirely considered until this point. By addressing the gaps in knowledge between previous work done in isolation, this approach presents a full consideration of prior areas of work within a feedthrough and feedback system to more accurately track and identify engagement behaviours in relation to user and system experience, ultimately leading to a more complete understanding of use.

Chapter 10: Conclusion and Future Work

This thesis was motivated by the limitations of interactive digital displays to support Multiple Independent Simultaneous Users (MISU's) to the full range of their potential as interactive and adaptive systems, when considering the maximised utility and mitigation of negative social phenomena through adaptation of layout. This thesis has identified and examined a number of natural social organisations relative to display use and presented a number of design recommendations for adaptive layout changes relative to the on-going social organisation and use. It has also developed a novel mechanism for the interpretation and classification of user behaviours between factors of the display and on-going use to deliver informed layout changes and adaptations. The results of this research provides a knowledge base for further investigations of socio-spatial behaviour relative to changing layouts and modelling approaches in describing behaviours relative to environmental changes.

This chapter presents the contributions to knowledge and areas of future work before concluding the thesis.

10.1 Contributions

This research has been built upon classic considerations of Human Computer Interaction, Museum Studies and Social Science Theories, and contributes additional knowledge to these fields for the design and use of interactive adaptive displays for MISU's. These contributions are now shown:

Through the review of relevant literature (Chapter 2) and the process of observations (Chapter 4), a range of factors of spatial and digital interaction were identified and investigated (Chapter 5) to consider the impact of on-going use between MISU's. This leads to a number of design recommendations for group dynamics around adaptive layouts and properties of content presentation. This focussed specifically on the research of factors of presentation and layout change in user experience as an indication of optimal strategies in achieving adaptation.

By further considering how natural entry and organisation takes place at displays relative to user awareness found through both socio-spatial and digital interactions (Chapter 6), a number of considerations were put forward in developing adaptations to best support natural use as an extension of optimal learned behaviours, but also in mitigation of natural organisational phenomena leading to poor use of the display and user experience (Chapter 7). This resulted in a number of design recommendations around the situation and presentation of content to users entering the space, and further considerations of how layout changes and adaptations might best support further entry and optimal organisations of users for consistent user experiences.

Finally, a simulation modelling approach was applied to the entry behaviour of users to evaluate the effectiveness in identifying approach and engagement behaviours relative to on-going formations of users at the display (Chapter 8). This considers how feedback and adaptation can be applied in an informed manner to limit the impact to current use, while effectively supporting the awareness and engagement of the user entering. The application of a modelling approach to this form of interaction goes to further support interpretations of feedthrough and feedback in the organisation of space, via an informed relationship of adaptation to known entry and approach behaviours and outcomes.

The contributions throughout have considered both positive and negative aspects of natural multi-users and system-led interactions across a variety of interaction modalities, to describe a design space which is both appropriate and effective in supporting user experience, but also geared towards the utility of the system and interaction design. This moves away from the one-dimensional approaches of either, system led adaptation relative to spatial metrics and models of engagement, or multi-user led interactions with responsive systems, to provide a system based interpretation of social organisations in parallel with the natural organisational behaviours of multiple users in social spaces. This introduces a novel concepts in Human Computer Interaction of a socially aware ubiquitous system to both support and mitigate actions and interactions through its behaviour.

10.2 Future work

The main considerations for this work going forward are found in the nature of assessment of social-spatial behaviours and the underlying mechanisms of interpretation, classification and prediction modelling of the system.

Greater investigation of display presentation and feedback should be undertaken to identify better mechanisms to capture the attention of users in establishing a relationship to a display where an interaction is on-going, with further mechanisms to support leading or structured interpretation of spatial behaviours and points of interaction. The relationship to points of engagement also present an initial opportunities for classification of approach behaviours, which are necessary to identify appropriate points in time and space to apply adaptations for optimal use and experience of all users.

Further work to consider a wider range of adaptation strategies as well as subtle factors of leading behaviours and feedback around adaptation will also offer a greater weight to the role of these systems and support wider design recommendations for alternate applications of these approaches. This information offers the potential for greater coupling between actions of the display and user response in a number of interaction scenarios, and works to allow an action-affect model within the prediction modelling approach.

Within the prediction itself, there is scope for multiple simulation approaches to be investigated in the hopes of identifying an optimal approach, however, the current configuration offers a strong solution to the problem space. The use of wider interpretation effects, such as gait, pose and body-action estimation would offer richer information in the classification problem around behaviour, awareness and intent, and would lead to higher accuracy in prediction relative to approach. In turn this would lead to better defined adaptation actions to support these behaviours.

Finally, the use of a forward interpolation approach to action-effects due to adaptation through a simulation approach, based on knowledge of users behaviours and user reporting in interaction and experience, would allow for adaptations to be applied at the most appropriate point of display relative to on-going behaviours. This would support a mechanism for spatial organisation and flow based in spatial design requirements, but also allow for minimal impact of real time corrections in system based errors.

While this list could go on, this has outlined the major considerations and limitations found in each chapter and suggests approaches to inter-relate multiple further aspects of research.

10.3 Conclusion

This thesis has provided a broad interpretation of multiple user interaction around large interactive and adaptive displays, with consideration of factors of presentation, feedback and adaptation of content layouts, with considerations of user experience and utility of the display. It has contributed to the research field by establishing a range of design recommendations for interpretations of display behaviour and informed adaptation approaches relative to on-going use, establishing an effective laboratory based test-bed system, and presenting the basis for a modelling and prediction approach for multiple user interaction leading to the application of informed adaptations to best support aspects of socio-spatial and engagement behaviours. Besides presenting a series of design recommendations, this work has situated the findings between the fields of interaction design and social interaction to provide a novel mechanism for computer led interaction.

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Appendix

See Volume II

Glossary of Terms

Adaptation: A system led change in the relative layout of content windows.

Altered interaction: Within Chapter 8: Study 4 – Predictive System, the classification of user Behaviour throughout an interaction may change between the entry and landing levels of interaction due to System or User led factors. These are described as "Altered" interactions.

Configuration: The arrangement of persons relative to the display i.e. Clustered or Distributed across the width of the display.

Layout change: An alteration to a component of the screen, including aspects of adaptation and presentation.

Formation: The local arrangement of persons with respect to points of interaction.

Multiple Independent Simultaneous Users (MISU's): A collection of users independently engaging with the system and points of interaction at the same time.

New Users: A participants entering the interaction space without prior knowledge or experience of the system interaction or mapping of content. This can include persons experiencing multiple trials within a study, but refers to person entering a space relative to a novel organisation or response.

On-going user: A participant who is engaged with the system before any adaptation or change in layout is shown. This refers to persons who are interacting with the space before any given threshold for spatial or display change is met.

Parallel (entry condition): Users enter the interaction space from the left hand edge of the display. This approximates the conditions of a hallway or display situated along a long wall.

Perpendicular (entry condition): Users enter the interaction space along the centre line of the display from a removed position with no initial line of sight before entry.

Presentation: The manner in which content is shown on the display, accounting for; size of content window, size of text, movement and nature of changes within these factors.

Proxemics: The spatial orientation of persons describing the nature of social interaction.

Public Large Interactive Display (PLID): A display of significantly dimensions to allow multiple simultaneous individual user interactions when accounting for personal space and gestural engagement. This also considers both interactive and adaptive displays based on the nature of system design and sensors.

Window (Content Window): A specific frame containing content aimed to be presented to a single user given the dimension and position on the relative display.

Wizard-of-Oz: An interaction conducted in a manner which represent a fully working system, while aspects of the interaction are pre-planned or controlled in real time relative to user behaviour.

How can people’s spatial behaviour be used to dynamically lay out content on multi-user, interactive screens, and how does this dynamic layout affect people’s spatial behaviour?

by

James Richard Burnett, MEng

A thesis presented to the

University of Nottingham

In fulfilment of the thesis requirement

For the degree of

Doctor of Philosophy

In

Computer Science

Nottingham, United Kingdom, 2023

Vol. II of II

Contents

Appendix A – Supporting the Methodology

A1 Research Ethics Checklist

The University of Nottingham

School of Computer Science

Research Ethics Checklist

for PGR students & staff

- This checklist must be completed for every research project that involves human participants, use of personal data and/or biological material, b*efore* potential participants are approached to take part in any research.
- Any significant change in the design or implementation of the research should be notified to cs-ethicsadmin@cs.nott.ac.uk and may require a new application for ethics approval.
- It is the applicant's responsibility to follow the University of Nottingham Code of Research Conduct and Research Ethics and any relevant academic or professional guidelines in the conduct of the study. **This includes providing appropriate information sheets and consent forms, and ensuring confidentiality in the storage and use of data.**
- Completion of this form confirms that you have read and understood the guidelines at www.cs.nott.ac.uk/ethics regarding:
  - what is defined as *personal data;*
  - what is required for *valid consent;*
  - the key requirements of the Data Protection Act
- The supervisor/principal investigator is responsible for exercising appropriate professional judgement when completing Section VI of this form.

- **Sections I to V should be completed by the student or researcher undertaking the study. Section VI should be completed by the supervisor/principal investigator.**
- The **supervisor/principal investigator** is responsible for emailing the completed form to cs-ethicsadmin@cs.nott.ac.uk, and for providing feedback to the student/researcher.

SECTION I: Applicant Details	
1. Applicant's name	James Burnett

2. UoN Email address	psxjrbu@nottinhgam.ac.uk
3. Status	**PGR Student**
4. Student ID (PGR students only)	**4192148**
5. Supervisor/PI's name	Holger Schnädelbach
6. Supervisor/PI's email address	**holger.schnadelbach@nottingham.ac.uk**

SECTION II: Project Details	
1. Project title	**The effects of responsive displays on social interaction**
2. Proposed start date and period of study	**01st July 2016 – 26th November 2016**
3. Is this a re-submission?	**No** (delete as appropriate)

4. Description of Project, including aims and objectives. *Please include any information which may affect the consideration of the ethics involved, eg location of study, unusual circumstances, age range of participants:*

Aims:

To investigate the relationship between the layout of large adaptive displays and social formations of users when in close proximity. This will consider the social interactions of multiple groups as well as the physical relationship to the layout of content.

Objectives:

*Observe and understand; How group interactions with a large display are affected by adaptation of layout which are mapped to the users movement in front of the display, as well as the influence this has on forming an experience. Further to this, the effects on approach behaviour as the result of adaptation and on-going interactions by other groups at the display.

*Group discussion; The perceived experience as the result of adaptation and interaction as well as further factors that could inform the design and application of these adaptations.

The System:

Provide a succinct description of the technology used and what it enables.

Location:

Work will be carried out in the Mixed Reality Lab (MRL) lab space, interacting with a large projected display. The immediate area will be surrounded with heavy curtains to isolate the experience from the lab.

Participants:

Will be aged 18+, and selected from an extended group of University of Nottingham (UoN) staff, students and researchers, as well as members of the public. Workshops will be run with between three and nine participants each with a mixture from each category.

When:

Studies will be run during working hours of 9 - 5. The study should last approximately 1 1/4 hours, with a contingency of an additional 15 minutes for late starts and discussions included in this time. Participants will receive a 10 – 15 minute brief and time to complete consent forms. The study itself will last for approx. 45 minutes, with an additional 15 minutes for discussion. The discussion may be longer or shorter depending on the group size and topics being discussed.

All participants will receive £10 /hour compensation in cash or high street vouchers, to a total of £15 for completion of the study.

What will happen:

Participants will be read the introduction and consent form, with points relating to data collection and recording highlighted to ensure informed consent. Several participants may be asked to adopt roles or personas in-keeping with behaviours seen in an everyday museum or gallery context. These may include a prescribed interest in specific content or theme or actions to be carried out during the studies. The actions should encourage physical interaction with the display and grouping behaviours between the group members.

The workshop will be made up of three short studies, where users will be asked to enter the space from varying positions in a randomised time order. Each study will investigate the mappings of content adaptation to user movement and how this affects the interaction and experience of each user in relation to the behaviours of others. These will last approx. five minutes each, followed by a short discussion of around five to ten minutes. After all studies are completed there will be a period of reflection for the whole workshop.

During the study participants will be asked to approach and interact around a large display (5 x 1.2 meters). This will require reading of captions and images at close proximity (around 1 - 2 meters). During interactions there may be several prompts from the researcher for participants to explain or encourage types of interaction. These would focus on expanding the behaviours of participants in relation to an adaptation or action seen on the screen. This would not require any action that would not be seen in a museum or gallery context or public setting, but may encourage participants to enter into a socially awkward situation in order to engender a response from others. Such as encroaching upon perceived personal space, or interrupting interactions around the display.

4. Will personal data or biological materials be collected, recorded and/or analysed?

Yes (delete as appropriate)

If Yes, please give details of the data or materials and the methods to be used and describe how safe storage will be maintained according to the Data Protection Act:

Data capture:

The system is a real time adaptive display mapped to the users relative lateral position in front of the display. The system uses Kinect cameras (depth and infra-red) to identify figures in the frame. The Kinect software is able to identify and track users based on "images" of the body within the camera frame. This does not require identification of the users and is completely ambiguous in terms of identification or tracking of an individual user. The system only uses the position of the users in front of the display to show content. This position is recorded as co-ordinates, with no additional identification data associated with the saved data.

Video cameras will be used to capture participant movement in relation to one another as well as adaptations of the display. Participants will be informed of the cameras and their locations before the study is conducted. The cameras will be placed behind the participants in order to minimise images of faces and reduce any intrusion upon the participants.

Further to this, audio recordings will be made of discussions both during the study and post study feedback. Participants will be informed of the use of audio recordings before the study takes place. The recorder will be kept with the researcher in order to achieve the best possible directional recordings as well as any ongoing discussions between participants. A further recorder will be placed at the display in order to catch conversations between participants about contents of the display. During use of the recorder participants will not be directly singled out, but instead the device will be kept in a neutral position to reduce and undue pressure on individuals.

All collected data will be stored in a Computer Science secure data repository in accordance with the DPA requirements. Only the researcher and supervisors will have access to this data.

SECTION III: Research Ethics Checklist (Part 1)

Please answer all questions:	**Yes/No**
1. Does the study involve participants who are particularly vulnerable or unable to give informed consent (e.g., children, people with learning disabilities, prisoners, your own students)?	NO

2. Will the study require the co-operation of a gatekeeper for the initial access to the groups of individuals to be recruited (e.g., students at school, members of a self-help group, residents of a nursing home)?	NO
3. Will it be necessary for participants to take part in the study without their knowledge and consent at the time (e.g., covert observation of people in non-public places)?	NO
4. Will the study involve the discussion of sensitive topics (e.g., sexual activity, drug use)?	NO
5. Will participants be asked to discuss anything or partake in any activity that they may find embarrassing or traumatic?	NO
6. Is it likely that the study will cause offence to participants for reasons of ethnicity, religion, gender, sexual orientation or culture?	NO
7. Are drugs, placebos or other substances (e.g., food substances, vitamins) to be administered to the study participants or will the study involve invasive, intrusive or potentially harmful procedures of any kind?	NO
8. Will body fluids or biological material samples be obtained from participants? (e.g., blood, tissue etc)	NO
9. Is pain or more than mild discomfort likely to result from the study?	NO
10. Could the study induce psychological stress or anxiety or cause harm or negative consequences beyond the risks encountered in normal life?	NO
11. Will the study involve prolonged or repetitive testing for each participant?	NO
12. Will financial inducement (other than reasonable expenses and compensation for time) be offered to participants?	NO
13. Will the study involve the recruitment of patients, staff, tissue sample, records or other data through the NHS or involve NHS sites and other property? If Yes, NHS REC and R&D approvals from the relevant Trusts must be sought prior to the research being undertaken.	NO

SECTION III: Research Ethics Checklist (Part 2)	
Please answer all questions:	**Yes/No/NA**
1. For research conducted in public, non-governmental and private organisations and institutions (such as schools, charities, companies and offices), will approval be gained in advance from the appropriate authorities?	N/A
2. If the research uses human participants, personal data or the use of biological material, will written consent be gained?	YES
3. Will participants be informed of their right to withdraw from the study at any time, without giving explanation?	YES

4.	If data is being collected, will this data be anonymised?	NO
5.	Will participants be assured of the confidentiality of any data?	YES
6.	Will all data be stored in accordance with the Data Protection Act 1998	YES
7.	Will participants be informed about who will have access to the data?	YES
8.	If quotations from participants will be used, will participants be asked for consent?	YES
9.	If audio-visual media (voice recording, video, photographs etc) will be used, will participants be asked for consent?	YES
10.	If digital media (eg computer records, http traffic, location logs etc) will be used, will participants be asked for consent?	N/A
11.	If the research involves contact with children, will the researchers have appropriate CRB checks?	N/A

- If you have answered 'No' to all questions in SECTION III Part 1 and 'Yes' to all relevant questions in SECTION III Part 2 the project is deemed to involve **minimal risk** - go to the signature page.
- If you have answered 'Yes' to any of the questions in Part 1 or 'No' to any of the questions in Part 2 the project is deemed to involve **more than minimal risk**. Please explain in SECTION IV why this is necessary and how you plan to deal with the ethical issues raised.

SECTION IV: If the project involves more than minimal risk, please explain why this is necessary and how you plan to deal with the ethical issues raised

Q4 - If data is being collected, will this data be anonymised?

A – NO

The Video and Audio data collected will not be anonymised as;

1) The data will be kept in a secure location with access limited to the Researcher and supervision team only.
2) Participant identities and names will be kept separate between consent, recorded data and publication to prevent identification of individuals.
3) Both Information and Consent forms will indicate the use of audio and video and will inform participants of their right to withdraw their rights to their image or personal data from analysis and publication, as well as removal from the study.
4) The position of audio and video recorders will be indicated to participants before the study. These will be located to cause the minimum of intrusion and distress to participants, as well as minimising frontal images which may cause participants to be recognised.
5) Any images used for publication will be suitably anonymised to protect participant's identities.

RESEARCH ETHICS CHECKLIST – SIGNATURE PAGE

SECTION V: Applicant Declaration		
Please confirm each of the following statements:		**Yes/No**
The project is deemed to involve **minimal risk** as defined in SECTION IV		**NO**
I confirm that I have read the University of Nottingham Code of Research Conduct and Research Ethics		YES
I confirm that I have read the guidance documents listed on page 1		YES
I confirm that the information provided in this application is correct		YES
Signature of applicant*	James Burnett	
Date	23/06/2016	

SECTION VI: Supervisor/PI Declaration		
Please confirm each of the following statements:		**Yes/No**
The participant information sheet or leaflet is appropriate for this research project**		
The procedures for recruiting participants and obtaining informed consent are appropriate**		
The data collection and storage methods are in accordance with the Data Protection Act		
Signature of supervisor/PI*		
Date		

- The **supervisor/principal investigator** is responsible for emailing the completed form, together with any information sheets and consent forms, to cs-ethicsadmin@cs.nott.ac.uk.

- The **supervisor/principal investigator** is also responsible for providing feedback to the student/researcher following Ethics Committee consideration.

SECTION VII: For completion by a School Research Ethics Committee Member	
Name of REC member	
Comments or suggestions	
Decision	**Approve** **Revise** **Reject** (delete as appropriate)
Signature of REC member	
Date	

On completion, an email confirming the decision should be sent to the **supervisor/principal investigator** with a copy to the student/researcher. The completed form will be kept by the School Office.

N.B. This was the initial ethics application which was extended in it's current form with each iteration of testing.

A2 Information Sheet and Consent Form

Adaptive displays design study – Information

James Burnett – psxjrbu@nottingham.ac.uk

Postal address: C/O James Burnett, office C6 Computer Science building, Jubilee campus, Wollaton Road, Nottingham, NG8 1BB.

What is it all about;

The adaptive displays workshop is a short lab based study of around 1 hour, to help evaluate the effects of display layout and adaptation on group formation and user experience. You will be asked to carry out a series of short tasks with other participants where your actions will be recorded using audio, video and position data. The tasks have been selected to encourage you to highlight components of the display and user behaviour which influence decision making and behaviour when interacting with this type of system. These studies are designed to allow you to comment on components of the display and will be followed by a short discussion to cover these points more fully.

What will be going on;

The study will be made up of several trials and before each starts we will walk through a short introduction to set the scene. Once the scenario begins, content will be displayed and you are free to interact with the display. It is important that you act naturally but are also thoughtful about your actions and any effects of the display that you notice, these are very important to the trial and we will discuss them at the end of each trial. Any changes to the layout will be live and related to your movement in front of the display which is tracked by Microsoft Kinect cameras, these will also be recording video data for later analysis.

After each study is completed there will be time for feedback on what happened and a chance to discuss the scenario with the group. The focus will be more towards ways the adaptation worked or didn't work in the scenario and what you might like to see done differently to help develop the ideas. Please keep this in mind during the study as we are trying to understand your thoughts and decision making during the experience. After all trials are complete there will be a short group discussion to discuss the entire experience.

Why have you been selected;

You have been selected as a participant to represent the range of user in a museum or gallery context to investigate the way you observe and interact with large adaptive digital displays. The study will be interested in the way you observe, approach and interact with these types of displays and how you interact with other people in the space and using the display while adaptations of the layout take place. Adaptations will be linked to your movement behaviour and your interactions with other users.

What is the information going to be used for;

Data captured by the system will include a path of your movement in front of the display as well as video of the space. This will be used to try and identify what the key factors were when entering the space and interacting with the display. The video data is used to confirm the layout and position of other users as you move through the space and to identify specific behaviours or interactions you might make. Still images may be used to evidence these behaviours along with specific comments or observations describing the scene.

As a follow up to each trial there will be an Audio recording of a group discussion. This will be used to identify your thoughts about the experience to find critical factors and behaviours when using this type of display. This information will highlight key behaviours but might also be used as a description of a particular scene or type of behaviour and might be related to actions seen in the video recordings or to describe your movement path in front of the display.

All information recorded will be stored in accordance with the Data Protection Act 1998 and only used in publications with express consent. Information relating to personal identity will not be published and images anonymised if requested. You also have the right to be removed from the study at any time, your information will still be kept but will not be included in the analysis. Please see the contact information above.

As part of the study AUDIO and VIDEO of your movements and comments will be recorded for later analysis, these will all be stored in accordance with the Data Protection Act 1998. Still images or Comments may be used in publications of the findings. Your contact details will not be publicised. Please also remember that you are able to withdraw from the study at any time, your information will be kept on record but will not be included in the analysis. To do so please contact me at the details at the top of the sheet. As compensation for your time you will be offered £10 or a voucher of equal value.

Adaptive Displays - Consent Form

The adaptive displays workshop is a short lab based study of around 1 hour, to help evaluate the effects of display layout and adaptation on group formation and user experience. You will be asked to carry out a series of short tasks with other participants where your actions will be recorded using audio, video and position data. The tasks have been selected to encourage you to highlight components of the display and user behaviour which influence decision making and behaviour when interacting with this type of system. These studies are designed to allow you to comment on components of the display and will be followed by a short discussion to cover these points more fully.

Please note, your data will be stored in accordance with the Data Protection Act 1998. All information will be kept in a secure location and may be used in publications and analysis of the effects.

Please read through this list carefully and initial the items to show that you give consent.

I have read and understood the information sheet provided which includes Information about the data to be collected: ____

I understand that I can withdraw from the study at any time by contacting the researcher at the address provided on the information sheet, and my personal details, audio and video data will be kept but not included in the analysis or publications, but only prior to any publication already made: ____

I understand that audio and video will be recorded during the workshop: ____

I understand that audio devices will be used to directly record group conversations: ____

I consent to personal quotes or images being used in project reports and publications in an anonymised form: ____

I consent to personal quotes or images being used in project reports and publications without anonymization: ____

I confirm that I have read and understood the information provided above and that I am over the age of 18, and that I would like to take part in the workshop:

Name: ………

Signature: ………

Workshop date: ………

Email: ………

Researcher Name and Signature:……………………………………………………………………………………

Appendix B – Wizard-of-Oz Findings

B1 Trial 1 Workshop 1

Layouts

Study One – Layouts

During this study a series of screen layouts will be tested to inform upon the effect of position of content windows on social interaction and group formation. The study will be conducted using a top mounted projector and smart board with the output masked to create a wide shallow strip of display area approx. (3 x 1 m). As seven non-equal internal positions will be used for the window display, an internal frame of reference will be employed to describe these locations. The display will be broken down in to two "screens", each of the same dimensions (1.5 x 1 m) to represent each half of the display. The join between the two will not be represented digitally but will simply be used to describe the locations of the displayed windows (See Fig. 1).

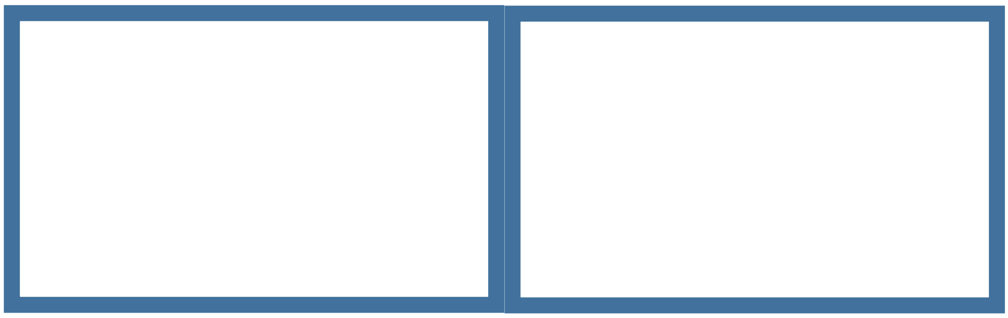


Fig. 1: Two separate physical screens with the adjacent bezel forming a separator within the display. The white space represents one continuous digital desktop to display content windows.

As the final screen will be a single continuous desktop display the absolute positions of content windows will be referenced relative to their position within the two screens described above. The screen selected and the internal position are described as such i.e. (Screen [Left / Right] / position [left/centre/right]) (See Fig. 2), where; Window (1.) is positioned in the left hand side of the left screen and is described as Left/left. Window (2.) is positioned centrally in the right hand screen, described as Right/centre.

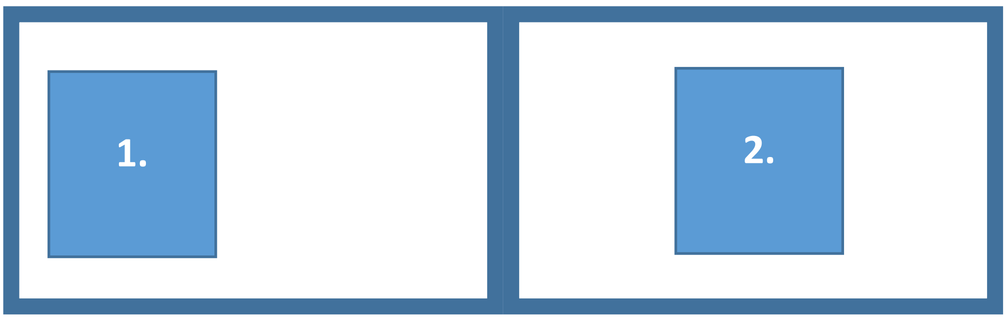
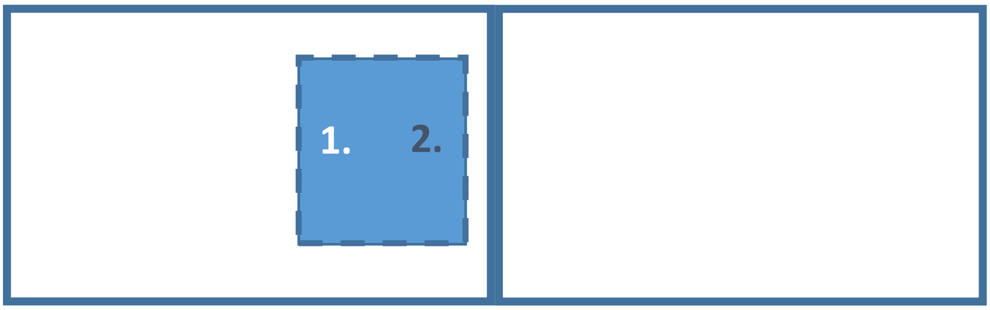
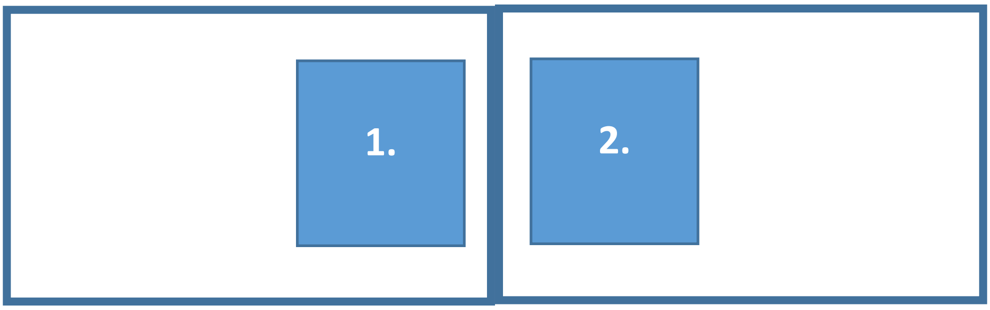


Fig. 2: Two separate windows within the extended display. Window (1.) positioned at Left/left and Window (2.) at Right/centre.

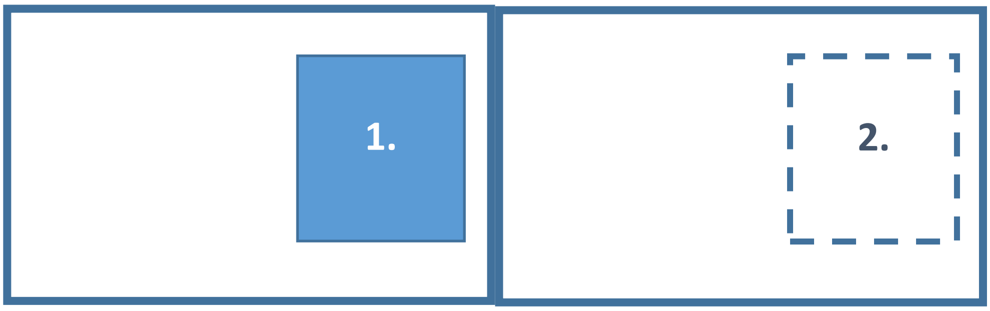
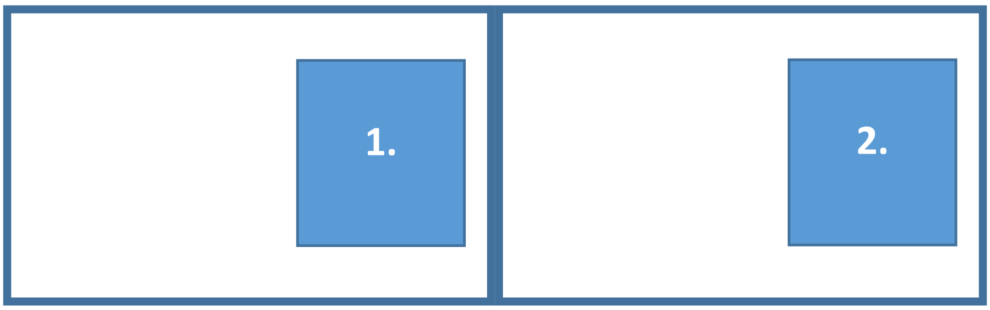
The content of the windows will be a series of power point slide shows, with a separate layout for each study, comprised of **five** slides each with each slide being shown for **six** seconds with **two** complete iterations of all slides to make a total of **one minute** per layout. To describe the adaptation of each layout a **before** and **after** layout will be shown for each study i.e. Fig. 1 (before) would show no Windows, while Fig. 2 (after) shows two windows immediately appearing with no transitions.

Section one: Considering the position of two windows

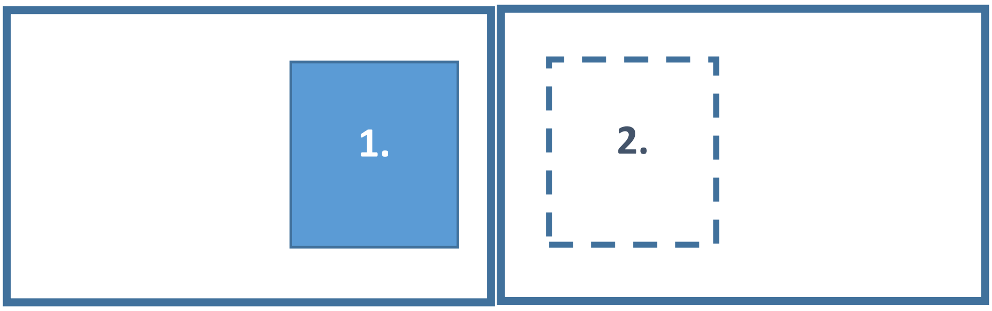
1.1 - Two Windows: Static layout [Left/right, Right/left]


Window (1.) will start at Left/right, with Window (2.) positioned immediately behind (1.) but not visible yet still displaying the same content.

After 2 slides (12 seconds) window (2.) will transition from behind (1.) Left/right to Right/left.
Expected outcome; As both windows will be in extremely close proximity I expect most participants will be clustered around window (1.). As window (2.) appears the cluster will expand to encompas both windows without breaking group coherancy.

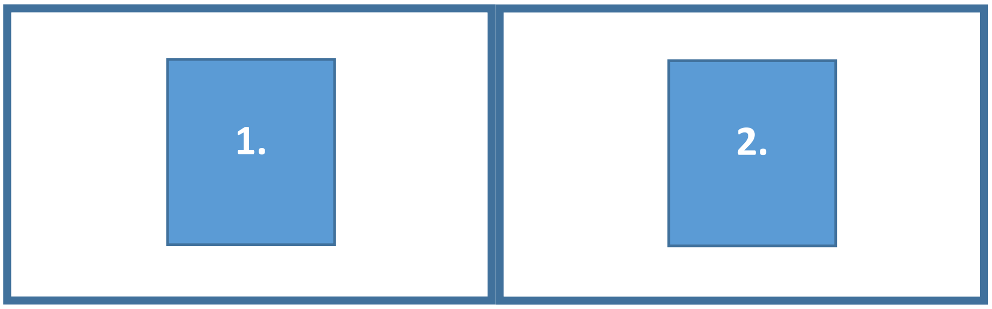
1.2 - Two Windows: Right hand bias – Static layout [Left/right, Right/right]


Window (1.) will start at Left/right, Window (2.) will not be visible.

After 2 slides (12 seconds) Window (2.) will become visible at Right/right (See above) displaying the same content as (1.).
Expected outcome; This may be a critical scale for interaction. The dimensions will likely encourage the group to separate as there is still proximity for social interaction yet this will be dependent on the number of people (3, 4 , 5+) at (1.), however, at this number it may be that separation will be subjective to the participant(s) nearest to window (2.) and the overall composition of the group. Either the group will form an equilibrium around (1.), which is in a central position yet this may break after a period of time, or there may be an immediate split when (2.) becomes available depending on the composition of the group and perceptions of the individuals. The extreme position of (2.) may have an influence over participants i.e. On the edge, external to the group centre, and could be considered for more focused interaction. The nature of the content and theme of the workshop may also influence the behaviours of participant's i.e. competitive / collaborative inference, or tightly coupled group engagement.

1.3 - Two Windows: Centrally positioned – Transition layout [Left/centre, Right/centre]



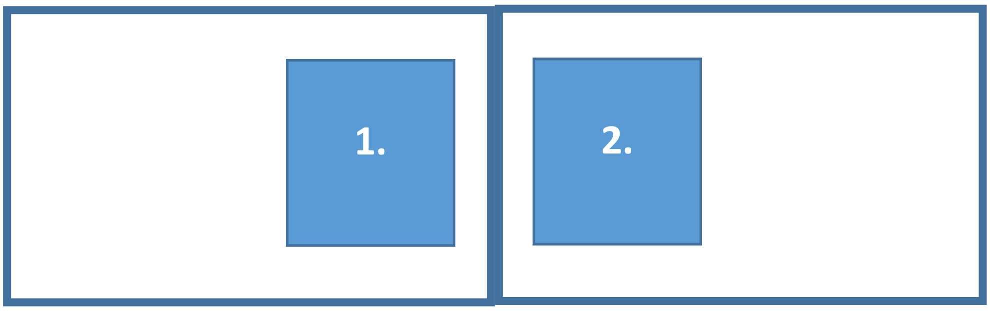
Window (1.) will start at Left/right, Window (2.) at Right/ left will not be visible.



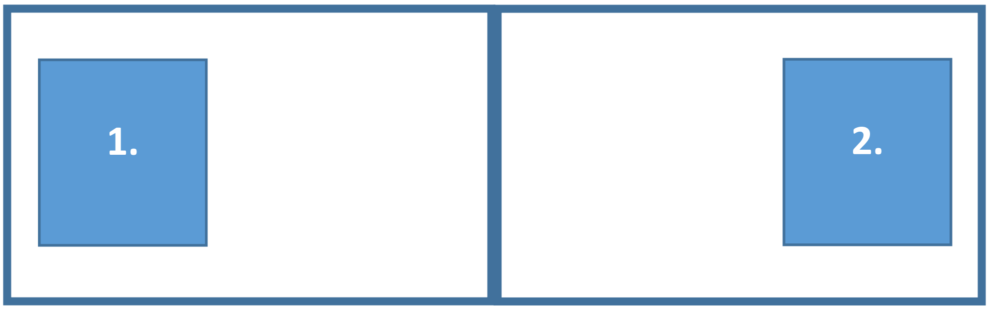
After 3 slides (18 seconds) Window (2.) will appear at Right/left (see above) and both windows (1. / 2.) will transition to Left/centre and Right/centre respectively. This study will use three slide transition to prevent participants from become over familiar with the adaptation rate and trying to pre-empt any changes. This will also aid with engagement with content and adaptation.

Expected outcomes: With the extended time (18s) the group should cluster around Window (1.) this may result in participants looking for an adaptation, trying to pre-empty the system. By creating Window (2.) adjacent to the first it will be very obvious to users and will also lend symmetry to the animation of both screens during adaptation. This symmetry and proximity to the group centre (approx.. the centre of (1.)) may prove effective in dividing the group as half follow each window. The close proximity (one screen width) may allow for social interaction across the windows, yet it may also be sufficient to encourage two separate formations about each window. This outcome will likely be dependent on the number of participants with a greater number more likely to form independent clusters as a result of the adaptation.

1.4 - Two Windows: Maximum separation – Transition layout [Left/left, Right/right]



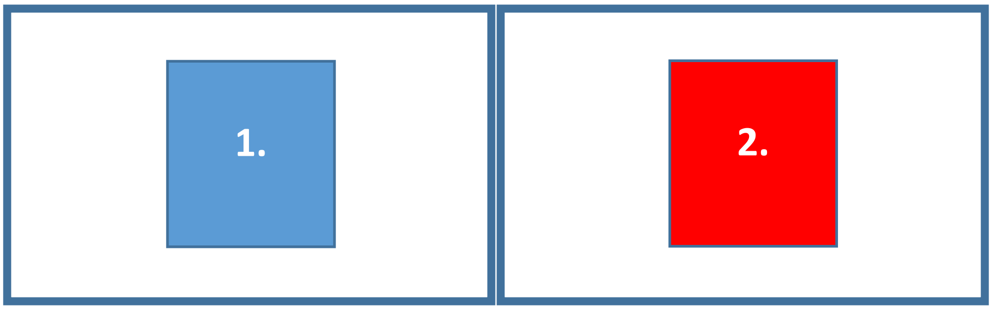
Window (1.) will start at Left/right, and Window (2.) at Right/left. Both will be displaying the same content.



After 1 slide (6 seconds) the windows will transition to their respective extreme positions. (1.) to Left/left and (2.) to Right/right.

Expected outcomes: By having the windows located centrally to the display this will cause clustering about the middle point, although this may be dependent on the number of participants (fewer participants may take separate windows each). The quick transitions (after 6 seconds) will take participants by surprise and cause a quick decision to be made as to direction.
If the group is clustered about the middle position It may be that all will follow one window (wanting to maintain group coherency), however, once the final position is known there may be movement between windows to find a balance of participants at each.
Due to the separation participants may check the content of each window or discuss the content to be sure nothing is being missed.

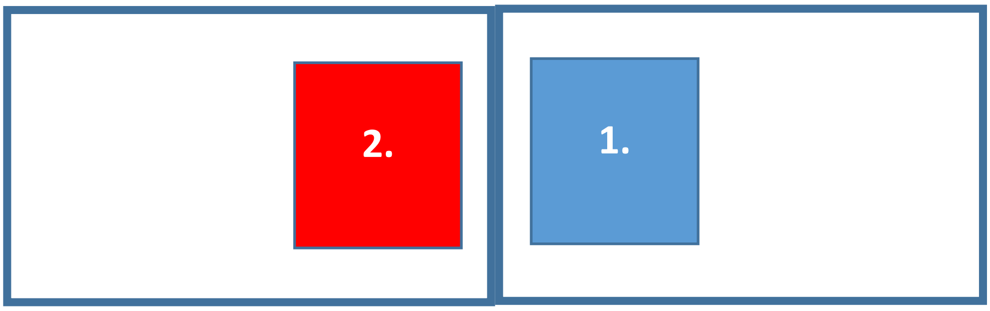
2.1 - Two Windows: Different content – Static layout [Left/centre, Right/centre]



Both windows will start at Left/centre and Right/centre respectively. Content will be played normally, with 5 slides, each shown for 6 seconds and then the whole show repeated.

Expected outcomes: As both windows will be visible from the beginning participants will have to choose which window to engage with, this will be subjective to content. However, as the windows are in close proximity there may be some discussion as to the nature of the content in each, comparing what can be seen and the information displayed.
As the content is repeated there is the possibility that participants at each screen will trade places when the slides begin to repeat in order to engage with the alternate window. This may result in a complete change of location or result in a hybrid arrangement of a cluster forming approximately in the centre of the display such that all participants can see both windows, with a tendency to be closer to the newer content for each group respectively.

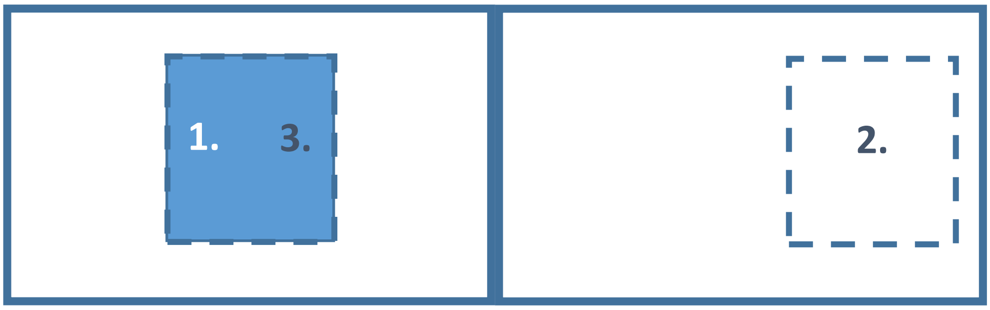
2.2 - Two Windows: Different content – Static layout [Left/right, Right/left]



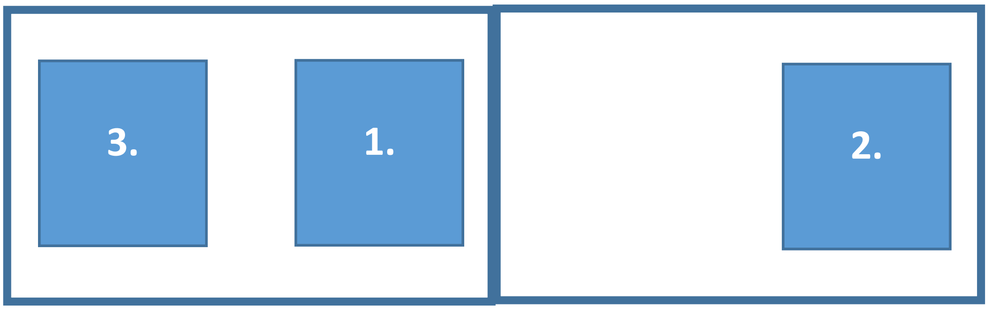
Both windows will start at Left/right and Right/left respectively. Content will be played normally, with 5 slides, each shown for 6 seconds and then the whole show repeated.

Expected outcome: Participants may either; Form a cluster in the centre of the display to pre-empt the change of focus with minimum disruption, or cluster about each window independently and physically transition as the slides repeat. The outcome will likely be dependent on the composition of the group(s) and the relations between the centrally positioned member(s) and those adjacent to the windows, as well as the initial cluster formations.

3.1 - Three Windows: Two left one far right – Static layout [Left/right, Right/right, Left/left]



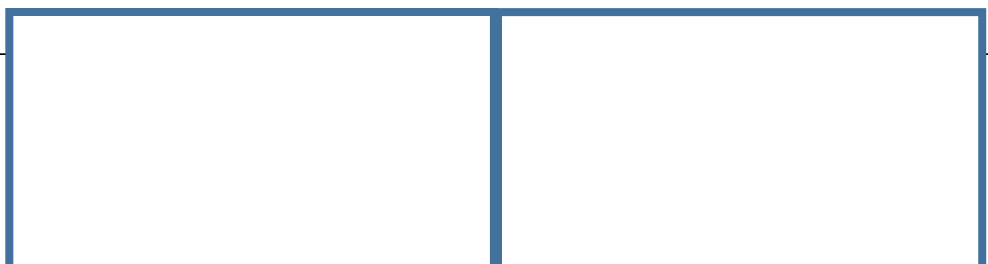
Window (1.) wil start at Left/centre, with window (2.) not visible at Right/right and (3.) behind (1.) at Left/centre, also not visible.



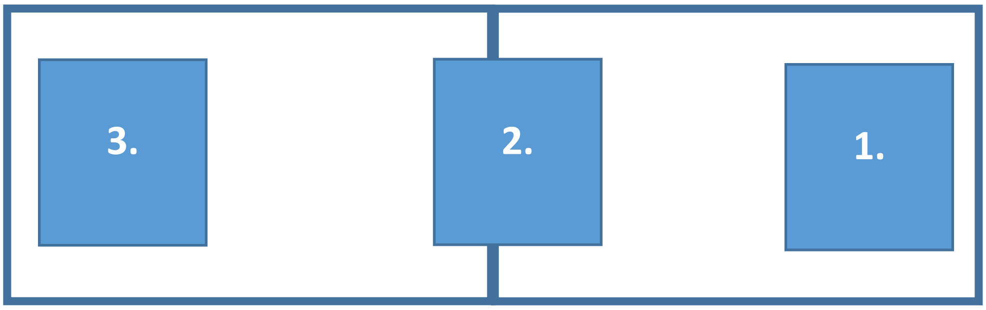
After 2 slides (12 seconds) Window (2.) will become visible and Windows (1. / 3.) will transition to Left/right and Left/left respectively.

Expected outcome: As the initial window (1.) is positioned centrally within the left screen, the initial cluster will form to the far Left of the display. During adaptation two windows will form on the Left screen, this will allow for a larger group to engage with the content with only a small change in formation and without having to significantly change position. However, the location of the right hand window (2.), will allow for significant fragmentation of the group. This will likely be the case if an individual or sub-group would like to engage with the content more directly than is permissible while part of the larger group. This outcome will be dependent on the formations of the larger group around the two left hand windows (based on dominant members and sub-group formations) and the levels of engagement with the content.

3.1 - Three Windows: Equidistant layout – Static layout [Left/left, Centre, Right/right]



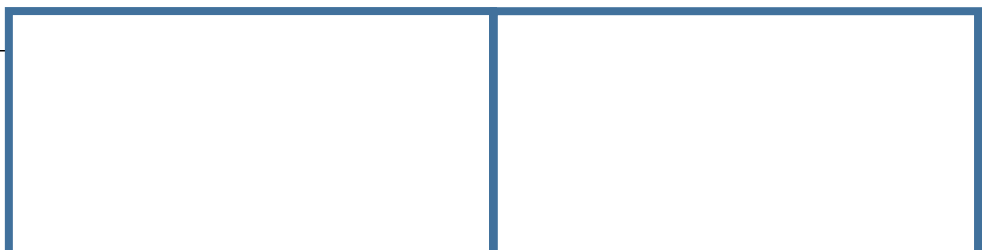
Window (1.) will start at Right/centre. Windows (2. / 3.) will be at display Centre and Left/left respectively, these will not be visible.

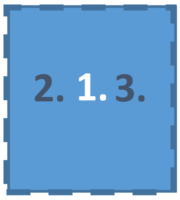


After 2 slides (12 seconds) Window (1.) will transition to Right/right and Windows (2. / 3.) will both become visible.

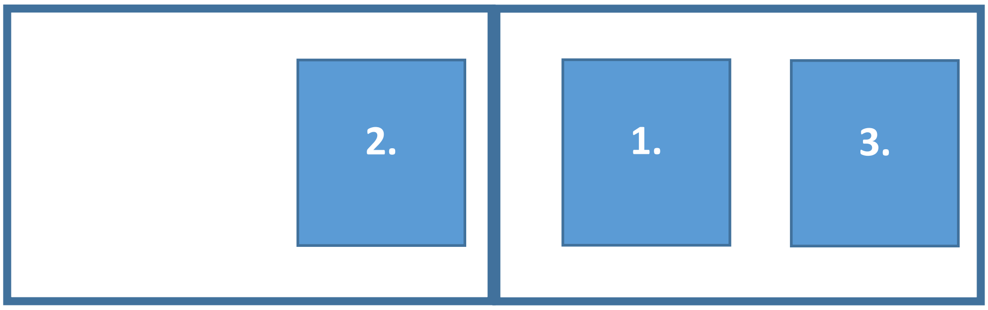
Expected outcome: As the initial cluster will form around the Right screen this may limit the observability of new window forming on the Left screen (due to the size and orientation of the group), however, the central screen will draw attention to the adaptation and encourage searching behaviour. Upon formation of the new windows there will likely be a fragmentation of the initial group, however, it may be that only a small number of people break away and claiming “ownership” of a window, particularly window (3.) due to its distance from the initial group centre.

3.2 - Three Windows: Two right one central – Transition layout [Right/left, Left/right, Right/right]





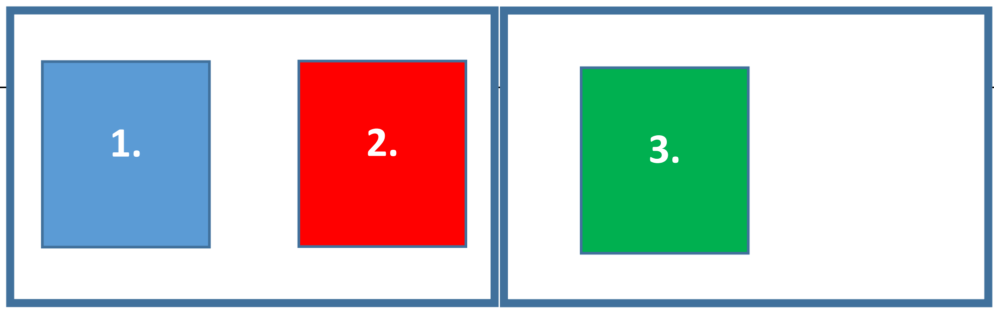
Window (1.) will start at Right/left, with windows (2. / 3.) positioned behind but not visible.



After 3 slides (18 seconds) windows (2. / 3.) will transition to Left/right and Right/right respectively. The final positions will be equidistant – This may require window (2.) to be adjusted to match the layout, not following the exact positioning of [Left/right] as described earlier.

Expected outcome: A prolonged time of 18 s is used to encourage a tighter grouping around Window (1.). This should encourage engagement with the content and generate a strong response to the adaptation of the display, which will be obviously animated from behind (1.). As the initial grouping is expected to form at the Right screen the adaptation will cause the group to split over the newly formed screens. This layout should allow for a wider formation allowing conversation and discussion across the windows without the group needing to split in to sub-groups (this will be dependent on the nature of the content and the levels of engagement generated in group interaction).
It may also be the case that the group forms around the Right screen (due to the physical presence of the bezel) and only one or two participants move off to the Left screen for a more focused engagement.

3.3 - Three Windows: Different content – Static layout [Left/left, Left/right, Right/left]



All windows will start visible displaying separate content. Each window will be equidistant such that window (3.) may need to be positioned differently than [Right/left] would describe in earlier examples. The slides will be repeated three times to ensure that each can be viewed separately. Participants will not be told this beforehand and so the expectation will be that the interaction will end after two iterations.
Expected outcome: As there is a wealth of content to engage with there may be several approaches adopted; A cluster may form in the centre to try and engage with the maximum number of windows – with either observation of each slide in series, or switching between one or two windows and then moving focus to the third window as the slides begin to repeat. Alternatively, individuals may try to engage with each window separately and move along the line. With the expectation that the content will end after two iterations there will be an impetus to view all content quickly, causing a higher fracturing of formations and more adaptive social interaction to manage the situation. The inclusion of a third iteration of content will allow for revisiting content and should encourage more engaging interactions and formations about the windows. The observed behaviours will likely be highly dependent on the initial engagement, such that whichever strategy is adopted will exclude the other. However, it may be seen that dominant members may be able to maintain a contrary approach to the group simply by maintaining their initial interaction and forcing other participants to adapt their behaviour accordingly.

Transcripts

<u>Study one – Transcript</u>

<u>Introduction:</u>

The introduction was very long and disjointed. Due to several participants being late and there being time constraints the documents were handed out for participants to read. It was commented that the document was very long and was only skim read. To ensure all of the information is read thoroughly and the concept is understood the document should be read out as a group to be sure people understand what is required.

The document itself is vague and does not have a clear direction or requirement form participants. The introduction does not accurately describe a scenario or context and so participants are unsure as to what actions are appropriate. On one hand there is a drive to engage with the content, in particular the windows, yet also having feedback forms introduces another element to focus on. Participants are both encouraged to observe the content (as there will be questions afterwards) and take notes on the layout / experience / interactions. The feedback form itself has several redundancies which are not well explained, in particular the multiple elements of screen layout and participant position. This is the information that the observer will be collecting and actually detracts from the user experience when having to consider all of these elements.

The introduction asks participants to stand around 2 meters from the screen before the study start, then, once images are displayed they are able to approach as they see fit. This was enforced by using a physical barrier behind participants to condense the effective movement space. Before the study started there were requests to move this barrier back as the space felt uncomfortable. This resulted in participants starting around 3 ½ meters from the display and having more space to move freely.

<u>Study 1:</u>

Description: One window at Left/right – Splits to form a second window at Right/left

The initial starting position was approximately 3 1/2 (m) from the display in a rough semi-circle. This was far enough back that all participants could clearly see the window and read the content, such that when a new window formed there was no need to move or adjust position. Further to this, participants were busy taking notes and trying to document feedback during the study.

Immediately after the study there was a short period for individual note taking, in this time there was some discussion between participants;

Question (Q) - “Were the screens different?”

Answer (A) – “I couldn’t tell the difference between the screens, I was taking notes”

After a few moments for all participants to finish their notes the content based follow up question was asked. This was intended to be directly related to the content displayed and light hearted to put participants at ease and encourage conversation. None of the participants were able to answer the question as they had not been able to pay attention to the content. There were several comments related to the images and key words, but they had been noted down as though the study was a test. All participants indicated that they had put almost all of their focus into completing the feedback form throughout the study which had required all of their attention, there was also some confusion as to exactly what was expected as a result of the adaptation and how this related to the questions on the feedback form. At this point I (the researcher) explained the expected orientations and the intended effects of the adaptation just seen, as well as points from the form;

Researcher Q (RQ) – “Did you notice any movement of the windows or other participants?”

A - “I was concentrating (on the form), I didn’t pay attention to other things”

At this point it was explained that the interaction with the content and in particular, the location and adaptation of the windows, was the key factor and that the feedback forms were of less importance. At this point we move on to Study 2.

Feedback forms: As participants were standing off from the display the first study was an exercise in observation. There were several references to the second window forming and shifting their gaze when it did, but there was no motivation to re-form the group as all were at a comfortable social distance and could still observe the material.

Adaptation was generally indicated well by wire-framing of the layout, usually with some indication of the order and a viewing direction. All participants identified their position in relation to the display but there was no absolute or relative movement given the large viewing separation. Instead participants would stand and observe the content whilst trying to make notes on the adaptation behaviour.

It was noted by one participant that when the second window appeared this was a positive adaptation as the content was now much closer, yet there was still no engagement with the content itself. As part of the feedback one participant gave key words relating to the images but did not read the captions as the transitions were too fast, which was something noted by several others. The general consensus was that there were too many factors to address and too much attention was given to the feedback form instead of the windows.

Some of the more interesting comments related to the large amounts of empty "wasted" space across the display and the duplication of content over windows, this will have been due to the fact members were standing back and not directly engaging with a "personal" window. Another point raised was that "there's nothing exciting happening" in the adaptation, again this is due to the observation approach and participants not directly interacting with the content.

Key Points:

- There was no motivation for participants to engage with the content. It was easier to stand back and observe the adaptation. This was also due to confusion as to the motivation of the study, as well as a need to fill in the feedback form.
- Once a stable formation had been formed 'one' participant would not move to a better positions (as there were too many other factors to address, such as the form, without having to get a better view of the content), but commented that the adaptation of a new windows nearer was positive as they could then interact. This is possibly a combination of social interaction causing them to stay in their starting location, confounded by the need to complete the feedback form.
- Participants commented on the amount of "wasted space" as a result of the lack of proximity of interaction with a single window. This is a combination of lack of context and the nature of the content allowing participants to stand back and "observe" the adaptation taking place.

Study 2:

Description: Two Windows: Static layout [Left/right, Right/left]

After the discussion follow the previous study one participant moved directly towards the screen in a playful manner in an effort to block the view of the others, and so encourage movement and grouping around the windows. The remainder of the participants remained in a stand-off position to watch the events unfolding but were forced to adapt their behaviour slightly in order to see around the participant at the display. This behaviour did not last long as participants still worked to complete elements of the feedback form, particularly at the point of adaptation. This may have been to accurately document the technical components of the adaptation (which was not the intention of the form). At the point of adaptation all users were then able to comfortably see the content windows without needing to adjust further, this resulted in the participant standing at the display to move back to observe both windows in order to establish what content was being shown on each.

After the study there was a shorter period of note taking which quickly progressed in to an open discussion regarding the nature of the interaction;

R Comment (C) – "The intention is to have direct interaction with a window"

C – "There needs to be some way to force people towards the display"

This conversation then expands in to a discussion around the intended interaction and outcomes of the adaptation, where the stand-off observations of the participants is not delivering the intended outcomes. There are then further discussion of context;

C – "The phrasing should indicate a museum experience or study"

This speaks directly to the nature of the interactions of all participants, indicating the need for a more tailored experience / context towards what is being displayed and/or the interaction that should be achieved. The discussions about the interactions are quickly proving to be far more effective than documenting feedback and in fact the act of documentation is detrimental to the interactions that the adaptation is aiming to facilitate.

Feedback: Feedback is much sparser than the first study. The wireframe descriptions of the adaptation give an indication of the change but do little to inform the interaction, other than one participant who identified that the new window was closer to their position and they shifted their gaze. The main observation was the relationship of these windows to the previous configuration, noting that these were closer together.

There was little description of the impact and instead the space was used to take notes on the content. This indicates participants were more engaged with the windows themselves and further comments suggest that the duplication of content at such small separations was not ideal for observers. However, this participant had selected a central position and as such had a direct view to both windows, this resulted in distraction caused by moving images in the peripheral vision. On the other hand, as noted earlier, bringing the window closer resulted in an improved experience. It is interesting to note that the participant did not move closer to the window initially, however, it is unclear if this was due to the stable formation permitting a clear line of sight or an unwillingness to interfere with others views i.e. getting in the way. Additionally there is also the consideration of completion of the feedback form.

Key points:

- Given a better defined context users will interact directly with the display / windows. The effects of this are clear on other participants who will adjust their position / behaviours.
- With better understanding of the interaction there is little use for the feedback, however, it does still offer some interesting personal perspectives from different viewpoints.
- A richer context is required to encourage interaction and feedback should probably be removed during the study.
- Participants note that adaptations bringing windows nearer are beneficial yet there is no initial movement to interact with the window when they begin far away. It is unclear if this is relate to the nature of social interaction (turn taking / not interrupting somebodies view) or a by-product of completing the feedback form in-situ.

- The discussion session provide much richer data than the feedback forms, although the personal perspective still proves useful. It would be interesting to consider the group and individual perspectives, yet there would need to be a context for an individual's affect / effect around adaptive displays.

<u>Study 3:</u> Two Windows: Centrally positioned – Transition layout [Left/centre, Right/centre]

Description: Participants formed a large ring around the display in order to observe the adaptation. There was much less note taking about adaptation, yet there were several notes in regard the content. As the screen transitioned the group check the content of the windows and saw that it was duplicated and so moved away slightly to allow a wider field of view (there was no need to all stand around a single window).

C – "I checked what was in the displays and when I realised it was the same I moved away"

In general this sums up the interaction with the display. The most interesting aspect was the slight widening of the circle as a result of most members moving back slightly in response to the wider separation of the two windows. This allowed each to observe both windows and assess the content as well as responding to the altered position of their selected window.

Interesting points raised were the timing of the slides being too fast, particularly when addressing multiple windows. It was suggested that user interactions would raise interesting questions, particularly given the nature of multiple groups engaging with a single window (interaction / observers). This then led rise to the idea of forced formations and the effect of lines or triangles around windows, especially when directly manipulating content.

Feedback: The feedback was again much sparser than the first study. Although, there were comments about the position of the central window being easier for the group to observe, but with the adaptation it was convenient to stay still and then observe the nearest available.

In the extreme positions to the side of the display it proved difficult to be sure of the duplication of the windows and so multiple checks were made in regard the content. As such, it may be that some method is required to indicate a duplicate from original content to prevent confusion as to the nature of the adaptation.

Key points:

- The wider, dynamic separation of windows caused some members of the group to adjust their positions further from the display to better observe the content. This was due to an interest in both content windows to check for duplication.
- When there was a realisation of duplication interest was lost in one window resulting in the a slight move away (disinterest), opening up space for other participants.
- The introduction of direct content interaction would be very interesting as it the introduces a context for multiple interactions as well as raising questions of relationship between participants (interaction / observer).
- Including forced formations around displays would also lend strong influence to the effects of adaptation or the use of "actors" or roles to encourage unusual behaviour.

<u>Study 4:</u> Two Windows: Different content – Static layout [Left/centre, Right/centre]

Description: The wider separation of the windows meant that the central location was prime for observation and there were several participant trying to utilise this space. Taller members would lean over the should of the person in front to get a better view as their initial starting point had several people in front of the display. At the point of repetition this person quickly moved to the other side of the display where there was a less obstructed view and they could engage with the new content.

There were also participants who took a wide angle to the display, meaning they could observe both windows, however as to how effective this was is difficult to assess, in particular the interaction with the far window and not simply observing the same content twice.

However, the participant (P) in the centre did not seem to notice the separate content streams, even though they were aware of both windows;

C – "I don't like separate content"

P – "Were they separate?!"

A following comment suggested that there was an assumption the content was the same but started out of synchronization to allow interaction with one window or the other i.e. for two groups. However, it was noted that when the content began to repeat there were clearly two streams. This resulted in the movement behaviour described above, to better observe the second stream.

Interesting comments suggested indicators of the amount of content to be displayed, so allowing participants to quickly assess the nature of the separate windows i.e. how much is left and are they the same or not. It was also suggested that some form of direct content interaction would be beneficial as it would allow better control of the interaction, however, this would introduce several new aspects to the interaction, such as group formation and turn taking. A good point raised would be to introduce a group voting system to allow for a decision to be "reached" as to the nature of the content or transition. This would further support a group interaction instead of facilitating an individual. It was also noted that the lack of interaction (this was not elaborated upon) at the screen resulted in an irritating experience. This included both the lack of control over the rate of content delivery, which was noted to be quick by all participants, but also the proximity of two separate content streams was found to be frustrating. When focusing on either the secondary window would be in the participants peripheral vision and causer a distraction, especially when both were changing at the same time, however, it was also noted that had they been asynchronous this would likely have proven a greater distraction.

It was noted that each study has had a general theme of content, given a direct interaction a method of content coding or selection would allow users a much richer interaction, particularly for a more personalised experience.

Perhaps the key point was that the setting did not engender a particular type of response. It was very much a stand and observe interaction, meaning that there was little need for adaptive behaviour of the participants. In this case there was no adaptation of the display, although there was the need for some participants to move in relation to the content they chose to interact with, however, the point raised was that the introduction of new groups would result in a forced movement due to the understanding of turn taking at an exhibit. Again this raises the point of context and the nature of the experience.

Feedback: A common theme was that two separate content windows was actually annoying at that separation. Several participants reported that once they understood there were two distinct windows they would first observe one and then the other, but as has already been noted, the proximity of the two windows resulted in a distraction when attempting to interact with the chosen window. This could perhaps be the result of the content transitions themselves and the quick fade-in, fade-out that was used. Although this may also be the case that they were simply too close.

It would prove very difficult for participants to interact with only one window without knowing the content of the other first and then making the decision to move to the next given that they are able to see both windows when approaching from distance. This is similar to what was seen in the study, where participants would stand and observe both windows to assess the content and then select which they would interact with, hence resulting in the "annoying" outcome of a screen in the peripheral vision. Again, this relates to the way that the "type" (classification) of content is expressed to the users so that an informed decision can be made about how to approach the interaction. However, this relates to a "post-analysis" of "static" content already displayed and does not lend itself to adapting the display to what the user(s) need.

Key points:

- The layout resulted in there being a "prime" central location, however, it was still difficult for this participant to interact with the content. There was a poor understanding of what was being shown as it was too quick to compare both without a context for the information.
- With an understanding of multiple content streams, participants were more engaged with finding a viewing point at for windows. This involved either moving or taking a wide angle to observe both (un-like with the central position where significant head movement was required). However, even with comparing both, there was still a limited understanding of the contextual relationship between (within) windows.
- An indication of the volume of content (or context / type) was suggested, as it helps frame the interaction. Also, direct interaction with the content (in several regards) would improve the experience, although this could likely be mitigated by changing the rate of content delivery. However, the content is highly context dependant (static content to support another display – dynamic interaction for user experience?!).
- Separate windows in close proximity was found annoying – Distracting and difficult to keep up with what was being delivered. Too much information to digest, although this could be linked to the rate of delivery.
- Some indication of the "theme" or nature of separate content would help when selecting which screen to interact with, either for approaching groups (prefer one over the other), or when making a decision as to how to engage with the windows sequentially.
- Key is the context of the overall interaction. Were there other people meant to be approaching. Why should anybody move around the space or change which screen

they are interacting with. This should be better described and more dynamic interactions take place – People entering the display.

<u>Study 5:</u> Two Windows: Different content – Static layout [Left/right, Right/left]

Description: All participants moved extremely close to the display as a result of the content (“Where’s Wally”). The central position of the windows allowed multiple participants to interact closely with the left window while also observing the content of the right window.

Given this position of the two participants to the left hand side of the two windows (while still observing both), there was space for a third participant to interact with the right hand window for a short time, before disengaging due to the difficulty of the task.

The task was particularly difficult due to the low resolution of images resulting in several participants not interacting with the display. Of these one participant did not previously know the concept of the content and so chose not to engage. This was a point of discussion between the other participants who were not taking part, causing a secondary formation behind those interacting at the display.

The need for participants to get extremely close to the display was key to encouraging the types of social interaction key to the concepts of adaptive behaviour that were being investigated. It was noted that the higher levels of detail that were presented were key and more analogous to a museum context, where visitors expect to move close to displays to fully engage with the content of the exhibit.

Feedback: As expected there was little feedback with only two comments. The first was in reference to the low resolution. The second however, was more interesting. The participant noted their position as central and that their viewing behaviour was continually switching from the right to left windows. There is no reference to the content at each switch, however, it appears that they may have assessed one screen for the quality and potential to “find Wally”, then repeated this the second piece of content. Upon repetition the content they may have checked the content again to “pick up where they left off”. It is noted there are six separate glances, so perhaps they have given up after the repetition when they have confirmed their initial thoughts that resolution is too low, hence the changing glance behaviour.

Key points:

- The higher detail encourages participants to get extremely close to the display, however, quality of detail is extremely important as three of five participants did not interact.
- The close proximity of windows allowed two participants to interact with the content of both windows from an off centre position.
- The position taken in front of one window (while being able to interact with the second) allowed space for a third participant to interact and make a decision as to the quality of content.

- Given a freedom to select a position one participant picked an off central position so that they could easily engage with both windows to assess the ability to complete the task. The off central position then allowed other participants to engage if they so choose.
- The nature of a participant's behaviour will be evident as the select a position to interact with the content. Even if there is more space available there is consideration of others who may want to interact, even if this is detrimental to their own interaction.

Study 6: Three Windows: Equidistant layout – Static layout [Left/left, Centre, Right/right]

Description: Initially there was a single window to the right hand side of the display. All members formed a semi-circle fairly close together around the window. The study was deliberately slow in adapting to let participants engage with the content. At the point of adaptation the window being used moved to the right hand end of the display, this resulted in several members (to the left hand end) moving with the window as there was no alternative at the time. Immediately after the move had finished several other windows appeared (evenly distributed across the display), this allowed the participants to the left hand side to spread out to the new windows as the previous was now in an awkward position at the extreme and there were several other participants interacting at this window.

At the time of the adaptation the participants on the right hand side stopped looking at the content and looked across the window to see what the adaptation had been to see if there was new content available. When it was noted that all were the same all participants went back to interacting with the content. In terms of the left hand side of the original formation the participants spread out to interact with the central window (there was no need to move to the extreme left as the number of participants was low enough to allow comfortable interaction with only two windows).

The discussion after the study proved highly interesting;

> C – "Three windows felt aggressive! Why am I being shown the same information?"

The implication was that there was a message or reasoning for having three window showing the same information. Particularly given the close proximity of participants to the display when all three windows were being shown. It was suggested that three windows could be used to stagger content i.e. a new window would start at the beginning of the content stream and not simply duplicate what was already being shown.

A key point raised was that the number of windows should be proportional to the number of participants interacting. This may be due to the fact that the previous studies had been conducted with only two windows maximum and this was done with three. It was noted that participants only interacted with two of the windows directly, although there was observation of the third. This was due to the number of participants and the relative positions of the windows to the starting point. The relation of numbers was highlighted in regards content and how it should be distributed to a current group i.e. over multiple proximal windows, but perhaps further windows could display alternate content (as current participants may not be highly engaged with the current windows).

The comments suggested that bigger groups should be used, either the total number of participants to consider the effects of multiple simultaneous interactions with multiple windows, or alternatively having several sub-groups, each of which is interacting with a separate window and content. Again the point was raised that a new window should start the content loop again and not simply duplicate.

Post this discussion the group began to discuss possible ideas for further adaptations not seen in the study so far;

The relationship between content size and position of the users, or detail of the content that is delivered. This could also be related to the number of people in the group i.e. the physical size of the window, but also the content that is displayed in relation to the number of people interacting with the window. This could also consider where people are standing in relation to the display / window within their group as to what is displayed.

The final consideration would be to introduce actors or roles for participants to encourage / annoy other users. This could be used in a variety of ways to encourage / discourage behaviours and force movement. However, it would introduce yet another set of variables in to the problem space which would be difficult to isolate in the current configuration of the workshop. However, this does highlight the need for an understanding of interaction and context for both participants and context.

Feedback: There was only one comment which stated that when the windows transitioned to the right, all attention was focused on this. As such, the participant did not notice that there were new content windows for a split second as they were pulled along with the movement of the window, along with the behaviour of the group.

Key points:

- The group expressed more engaged interactions with the content. This could be the result of several factors; The extreme position of the starting window (near a corner) requiring the group to cluster more tightly to interact, the extended time before the adaptation to allow more engaging interaction, the removal of the need to provide feedback, in response to the content of the previous study.
- Perhaps due to higher engagement the participant to the left of the window moved with the display as it transitioned right. It was difficult to tell the effects on the participants in the centre or to the right of the display. It is likely that they moved fractionally to allow the rightward movement without giving up their position.
- The movement distracted participants enough to not be aware of the appearance of new windows, showing the effectiveness of window transition during a higher engagement.
- After the transition participants would be aware of the content of all windows, and when realising it was duplicated would return to the single window interaction. Although, it was noted that three windows displaying the same information was “annoying” and it was thought there was an implication or some underlying reason for having this many.
- Comments were made about the relationship of number of people (number of groups) to the number of windows and the content shown. It was stated that new windows should show new content (or start the loop again) and not simply duplicate what is already seen.

- The number and distribution of windows in relation to the starting point did not work for the size of the single group who were interacting. The group did not want to split past the two windows that were approximately near to the initial starting position.
- It was noted that several groups should be used to consider the relationship between multiple windows. There was further point relating the size of windows / content to the proximity and size of groups. Such that detail would increase with proximity or lower group size, this would also introduce the context necessary for the environment and interaction with content.
- The use roles or actors could be used to help motivate behaviours. However, this would introduce more variability in to the workshop and would not necessarily induce movement behaviours. Roles would prove interesting (guarded / talkative) however, it would be highly related to the content.

<u>Study 7:</u> Three Windows: Two right one central

Description: Due to the small font the group moved in to the display quickly in order to engage. The format of the content was much sharper and brighter, perhaps encouraging this behaviour further. It was suggested that a technical assessment of font sizes should be carried out.

Upon the adaptation there were three displays, all in close proximity to the start point, however, it was noted that this configuration did not seem "aggressive" as noted in the previous study.

C – "Not aggressive … I wanted to read the captions"

All participants were far more focussed on the content but it was difficult to know which windows were being observed as they were close together. Unlike previous studies where the group tended to interact with a single window when there was duplication, it may have been that due to the size duplication was considered alright and separation of the group across multiple windows was not considered a problem.

It was also noted that the speed of slide transition was too fast, particularly in relation to the smaller font as it proved difficult to read quickly. The key comment was that the participant did not want a separate screen as they did not want to be singled out. What was also noted was that the content appeared to "move to a participant". This may have been due to the close proximity of all to the single window followed by an expansive adaptation allowing the group to expand a little and engage with windows separately. This was considered a positive adaptation as they felt they had a personal window (although it was possibly being shared without their knowledge).

n.b. There were no feedback comments left.

Key points:

- Smaller font caused much closer interaction with the window and a tighter proximity of the group formation than had been seen before. It may also have been the case that the improved format and quality of the content caused the group to engage to a higher level.

- A suggested technical exercise in font sizes was recommended. This could also consider the rate of content delivery and the distance of participants to the window.
- The use of three windows was not considered aggressive in this case. The reason given was that the participant wanted to engage with the content, but it may also have been due to the size of windows / font being smaller, causing the group to be closer to the display and less aware of the size / imposing nature of three separate windows. It should also be noted that the three windows were arranged in a way that participants could all engage with windows while still maintaining the starting group formation. This may have made the experience more personal and created an understanding of ownership of the windows within the group, instead of the stand back and observe approach of three windows repeating the information.
- The speed of slide transition was too fast for participants, but it was noted that a separate window would not be beneficial. Instead careful consideration should be made towards group and content delivery. In particular the distance to the window and the ease with which content can be read.
- A participant noted that a window “came to them” during adaptation. This is clearly a benefit (especially given the nature of the content and their interaction with it). It will be interesting to investigate the relationship between the size of the group and the number / size of windows for interaction and how this affects the experience.

Study 8: Three Windows: Different content – Static layout [Left/left, Left/right, Right/left]

Description: This study presented three separate windows, each with its own content. The windows were positioned closely enough to encourage a single grouping, however, the separate content and speed of transitions meant that the group would form back away from the display in order to observe all windows. The large volume of information meant that individuals would talk about missed content amongst themselves, either as passing comments relating to something interesting or funny they had seen, almost as if repeating for their own sake.

The volume of information and arrangement of windows in such close proximity, as well as the synchronization of window transitions resulted in several comments to the effect;

C – “Felt like information was being pushed in to my brain”

C – “It’s like being in the Matrix”

Participants noted that it was difficult to concentrate on one window as the proximity meant there were too many distractions. However, images did help as you could quickly assess the information, yet it was difficult to tell if the content was related i.e. told a story or had a general theme (this was when content was presented as text only).

It was suggested that separate content should be presented to separate groups and that multiple streams should be indicated as to what windows are displaying what – so that groups can make an informed decision. There were also comments relating to the shape and position of the windows, as there were two distinct sizes (smaller windows displayed text only, larger contained text and an image). There was the assumption from more extreme (left/right) positions that the same sized windows would contain the same information i.e.

smaller windows to either side of the large window containing an image, as such the secondary small window was disregarded by those in extreme positions, only persons in the centre could assess the content of all windows and this was considered too much to process.

The key point was the proximity of the windows and the changing content. The conclusion was that, either the windows should be separated to allow the group to stand back, or alternatively, the windows should have been further apart to allow for separate interactions or less distraction between windows.

The final consideration was the motivation for the interaction;

C – "People do not go to museums to look at displays, they go to engage with the content"

This is crucial when designing the interaction and subsequent adaptation of the display. The content should be the driving factor for the interaction. The presentation and format of the windows should support the content, not simply be a vehicle for delivery.

Key points:

- The proximity of the three windows encouraged a single grouping, however, the volume of content was off-putting and forced the group to back away.
- The volume of information was overwhelming and meant participants were commenting on the "missed" content that was deemed to be interesting to the group i.e. funny, interesting.
- Proximity and rate of change made it very difficult to engage with the content - Overwhelming. Difficult to focus on one window, unknown themes, couldn't focus on one.
- Types of windows could have a relationship i.e. same size - same content. What was the relationship between window sizes – Small windows larger (pictures) windows.
- Extreme positions could not easily assess the content of extreme windows due to fear of missing out on content – No clear themes for content – Pictures allowed to skim content.
- Proximity to the number of windows made interaction difficult.

Summary

Workshop Summary

Both workshops were run as sensitising exercises in to behaviours around large adaptive displays. The first was run with a single group of five persons and considered how this group would adapt in response to a series of changes to the layout. The second workshop considered how multiple groups would approach and interact with a display, both when in use and in response to adaptation. Both workshops considered adaptations in the number and position of content windows, as well as translation of windows during interaction.

Introduction and running the Workshop One

The design and description of the workshops was critical in framing the interactions of the participants. This was well reflected in the first workshop where there were several key factors noted from the introduction that had a significant impact on behaviours, these included;

- The length of the introduction and how the key points and description of the activities are conveyed to participants. An overload of information resulted in confusion in the tasks and gave poor results in relation to the designed adaptations.
- The methods used for feedback were also poor, the use of a form distracted participant from the task and did not help answer the questions robustly. Instead an open discussion after the study gave extremely rich feedback on participant's actions.
- The number of studies and their length will affect how much useful information can be gathered. The first study was eight separate interacts, each of which was extremely short.

Based on the observed behaviours there was a distinct need to alter the introduction used as well as the design of the studies. A general reduction of content should ensure participants can focus on key points of the design and interaction, as well as condensing the experience to draw more valuable information in response to the designs used. The effects were mitigated in the first workshop by re-introducing each study and the intended interactions as well as removing the need for immediate feedback such that more natural behaviours could be observed.

Observed behaviours

A wide range of adaptation designs were employed throughout the first study, where the majority would investigate the number and position of windows. Based on these layouts there were several trends that could be identified;

- The presentation of content (Font size and Image quality) would directly affect how groups approached the display. Large fonts did not require close proximity to read and so the minimum distance to the display to observe was large. This would altered how content and adaptation were viewed and their subsequent impact.
- When presented with multiple windows, group members will attempt to assess the content of both to make an informed decision about how and where to approach. As such, the separation between windows would influence the position that the group would form in order to observe both windows – Larger separation will require a greater distance from the display to observe both content stream, although not all members will move.
- Extreme separation between windows would make observation of content difficult. If separation was too low then focus on a single window would be difficult.
- During high levels of focus a group might respond reflexively to adaptation, such as movement, duplication or re-sizing.
- There was an improved experience when adaptations (appeared) to respond to the groups formation (size and position(s)).
- Adaptations that did not seem to correspond with actions could be confusing but would result in adjustment of the group to understand the changes and re-engage.
- The single group were aware that additional groups would alter how they interacted.

The first workshop indicated that layout would influence how approach and interaction took place in real time and that adaptation would influence on-going behaviours. The assessment of content and decisions of the individual members about their interactions would directly affect the formation of the entire group. Without additional groups present all windows were considered for interaction and this would factor in how movement took place around the display.

Designing the Workshop Two

Initially, a technical investigation of the display and content delivery was carried out to find a minimum distance for readability based on the resultant stand-off effects seen in Workshop One. This was important to encourage groups to approach the display and interact more directly with the content windows. Focussing on fonts and the size of content window would indicate the number of people that could comfortably interact at a separation of 1 – 2 meters for groups of no more than five to give the best possible readability for all and encourage close proximity to the display.

Further to the technical considerations the workshop had a more condensed introduction and featured fewer studies, each of which had more focussed interactions and adaptations. Feedback was only considered in the discussion period after each was completed and would have a more directed set of questions based on the adaptations of the study.

These points were considered in the design of the second workshop and proved to give better results, however, there were further problems found in the running of the study;

- Participants were told the study was a real-time interactive experience, this caused a high level of focus on the technical interactions and the content that was delivered instead of focussing on the task.
- The study was done using prescribed adaptations and did not respond to actual behaviours. This resulted in confusion towards the system and gave poor responses to the selected adaptations.
- Groups were formed arbitrarily by the researcher resulting in poor group cohesion and unrealistic interactions between one another.
- Individuals in these groups would separate form “boring” unrelated content to form around content they found interesting resulting in more natural formations but poor grouping.

Running the study as an interactive “personalised” experience increased interest in interacting with the system and engaging with content, however, this did not match the nature of a natural group formation or their expectations of the content. This resulted in poor experience for participants and separation from the prescribed adaptations causing confusion at their underlying meaning and lacking responses in regards effect and meaning within the experience.

Observed behaviours

While the groups did not engage with the content windows as a single entity there were several interesting factors relating to their approach and observation of adaptations that indicated a response between groups and potential factors related to adaptation;

- When multiple windows were presented there may be adjustment and assessment of the content of each, resulting in confusion between groups and poor organisation at the display.

- Indication of ownership would improve the assessability of current layout and improve the understanding of potential interactions that could take place by each group.
- When adaptations take place with no clear indication or reason for the action there will be confusion as to the expected response.
- Groups do not like to be joined or share experiences unless there is clear need or indication as to why.
- Adapting the window of an on-going group without reason or indication of an approaching group, or when there is poor focus on the window, results a minimal adjustment of position in order to maintain the interaction.
- An approaching group will take a sub-optimal position and adjust around an on-going interaction in order to observe a window that they have ownership over.
- Approaching groups do not want to interfere with on-going interactions, however, these original groups will naturally adjust their positions in response to a new group in close proximity as the result of physical proximity and awareness.
- Physical proximity is considered between the individuals concerned and does not appear to result in adjustment to account for the formation of the approaching group.
- Groups would endeavour to assess the content of windows that they were aware of – with better understanding of content type a group would select where to interact and the focus on content would improve.
- Being able to select content within the group proved to be extremely engaging.

In running the workshop there were clear indications that adaptation can influence a group's formation relative to the display, however, without a clear reason for the adaptation there is little indication that arbitrary adaptation will cause any significant change to the on-going group behaviour. Whether the adaptation takes place during approach or interaction the general behaviour will likely remain the same and significant changes in formation will likely arise as the result of direct social interaction, however, changes in the information relating to ownership or content available could result in adjustment in formation and re-assessment of content.

Summary

The framing of the study will significantly influence the interactions that participants expect and also direct their focus towards component of the experience. This can include the groupings as well as technical delivery. As such a more descriptive and concise explanation of interactions should encourage more realistic behaviours and open discussions towards formation and decision making as the result of adaptation.

While there are a range of configurations and adaptations that affect formation, it is not practical to consider each of these in turn as there may be significant confounding or subjective factors that have not been accounted for. Instead there were several factors that seemed to have the greatest impact upon the group formation;

- Position – Relative to the layout and other windows for duplication or multiple streams

The starting position of windows will affect the approach and interaction behaviour in relation to the display and the surrounding features of the space. After adaptation the proximity of windows to one another will also affect the way windows are viewed. If separation is too low the windows will be distracting, whereas if the separation is high there is a need to adjust the viewing position to assess content, after which separated windows are ignored. It was suggested that content streams should have “themes” or indication of duplication to make quick assessment and interaction easier.

- Density/Fidelity of content – Number of windows or volume of information

If the number of windows in close proximity is too high then user will have difficultly assessing the content of each separately, particularly when content is constantly changing. Alternatively, if there is a large volume of information it is difficult for groups to all access what is being shown. This will relate to the presentation of the material or the number of directly related windows i.e. supporting.

- Presentation – The text and images used

The size of text and quality of images will directly affect the proximity of groups to the display. Groups tended to approach up to the minimum distance where they could engage with content, there would then only be movement in response to an action i.e. adaptation. With consideration of text size and image quality it is possible to encourage groups to approach much closer to the display in order to interact with the content by displaying smaller text or images.

- Supporting windows – Distinctly separate yet joined

Multiple windows related to a single piece of content was confusing as there was no clear link between the separate windows, resulting in users becoming distracted. However, if clearly related to one another it may be possible to have higher densities of content displayed.

- Ownership – Indication of use and relationship to a group or experience

Indication of ownership did not lead to any clear distinction of use between groups, it was noted that some members when bored would observe the content of other groups. However, if content was related to a specific group or sub-group as a tailored experience this may change how groups interact between multiple windows. The indication of content “themes” would further encourage natural formations around windows, where ownership was not considered.

- Size of windows – Could be presentation, supporting window or duplication

The physical size of the window will affect the way that participants interacted with the content in a similar manner to presentation. There was also an assumption made about the content shown based on the size and position of multiple windows. This factor is the least explored in previous workshops.

While there were multiple behaviours that influenced the outcome of the group formations, they cannot separately describe how an individual assessed content or made decisions that related to these formations. As the group is not a discrete entity made up of individual actions and beliefs, I feel it prudent to consider the actions of the individuals and how these relate to the overall group experience. In this way the group behaviour is described through emergent behaviours of the individual members that make it up.

Conclusion

While there are several factors that affect the group formation these do not directly account for the behaviours seen. The behaviour of a group is the result of the individual decisions made by its members relating to the factors presented above, while there is also a consideration of the intra-group interactions that will in turn influence these decisions. During approach and interaction there are considerations made by each member relating to what can be seen and interacted with and how this relates to the group organisation. Upon considering these factors the resultant position of each member constitutes a formation in relation to components of the display and the other groups occupying the space.

While there is evidence to suggest that adaptation of display components can directly influence the formation and behaviour of the groups, it is not clear which are the key influencing factors in these interactions. Instead direct social behaviours and interactions have a clear effect when organisation takes place around a display, yet these negotiations seem to focus on the individual to individual level and do not take into account the current formation or requirements for interaction of other groups at the display, so how the individual perceives the layout of the display and their group may highlight the key variables in the overall group formation.

While there are several variables that indicate the potential formation of a group in relation to layout there are also considerations of group interactions that must be considered to fully understand the emergent behaviour of the group. As behaviour cannot be directly influenced or managed during studies it must be considered separately from the layout variables stated above in order to better understand the key relationships taking place. This should prove an interesting source of further investigation.

B2 Trial 1 Workshop 2

Layouts

Study two – Layouts

The design of the layouts is set to a PowerPoint display size of 50 x 30 cm. This size is used as it simplifies the dimensions of the display and provides a simple framework for positioning of windows.

After initial technical testing it was found that window dimensions should be as follows;

Single / double user(s) – 4 - 6 cm wide

Double / triple users – 8 – 10 cm wide

Supporting windows – 3 – 4 cm wide

– Dependant on the number of windows on screen at the time

Depth is dependent on the volume of content to display i.e. pictures or large amounts of text. Minimum depth should be 5 – 7 cm. 8 cm can be used if there is a large amount of information or large pictures.

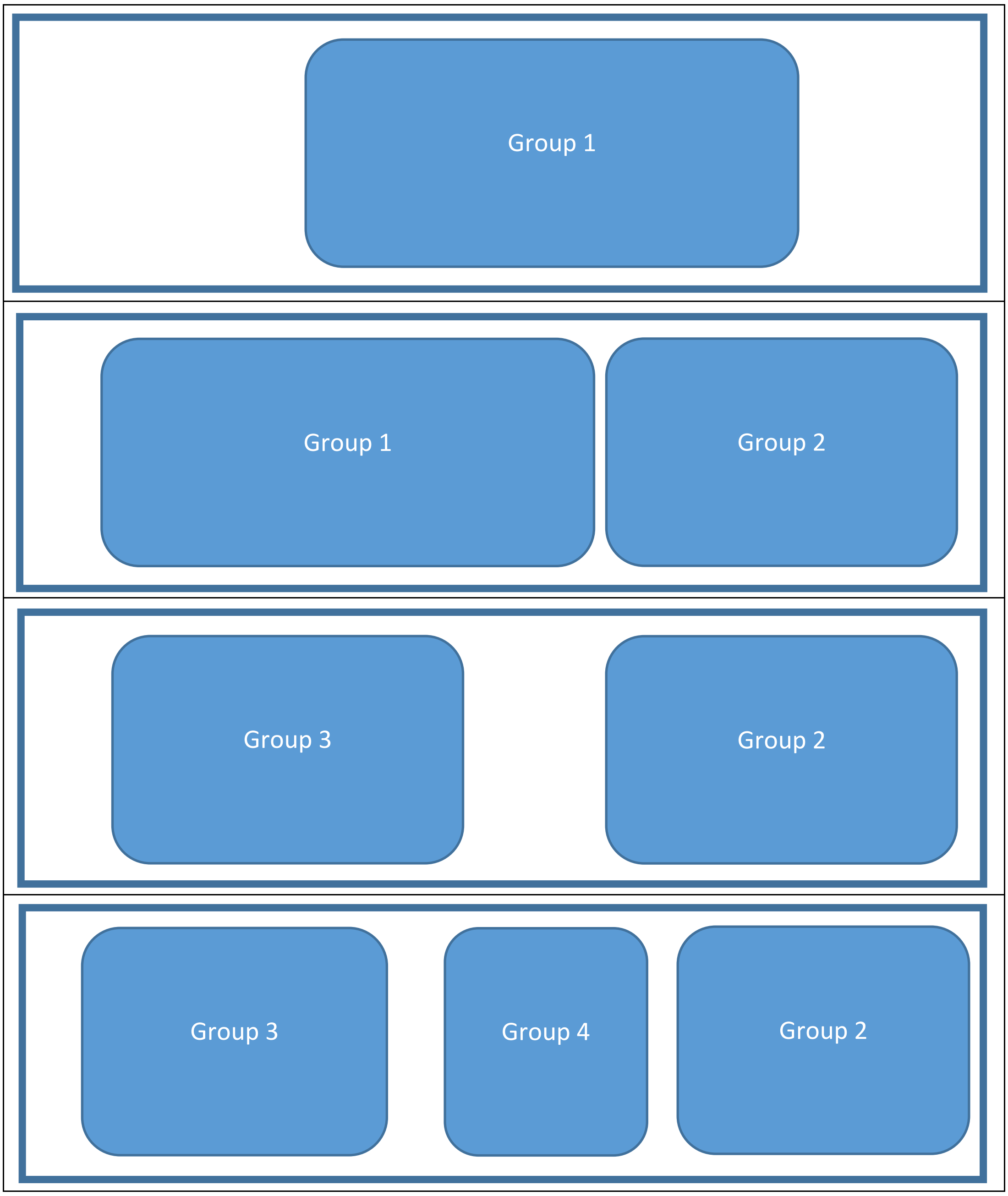
All text should be displayed at 13pt font to give the most readability given the low resolution of the projector, without being too large to be read from extreme distance. For the sake of clarity, captions can be produced at 14pt font, in this case supporting windows should use 12pt. This will give the required contrast in size to indicate the difference between the windows, without enlarging the font too much to allow separation of the group from the interactive region of the display.

N.B. These dimensions have been considered for use with the interactive board in the MRL at the specified dimension of the PowerPoint. Further changes may need to be made to the slide dimensions, in which case the window specifications will be updates.

Size of windows – Related to group size / position / approach

- Scaling windows based on current group and approaching requirements
- Adjust current window to allow entry
- Multiple entry / exits with re-sizing / positioning between

Start with a large window for a single group (3) interaction. Introduce a second group (2), as they approach re-size the first window and introduce a new window. Scale this up to give a relationship (3/2) between both. Have the first group leave and introduce new group (2), with a large window (3/2). Introduce group (1) and give equal window size.

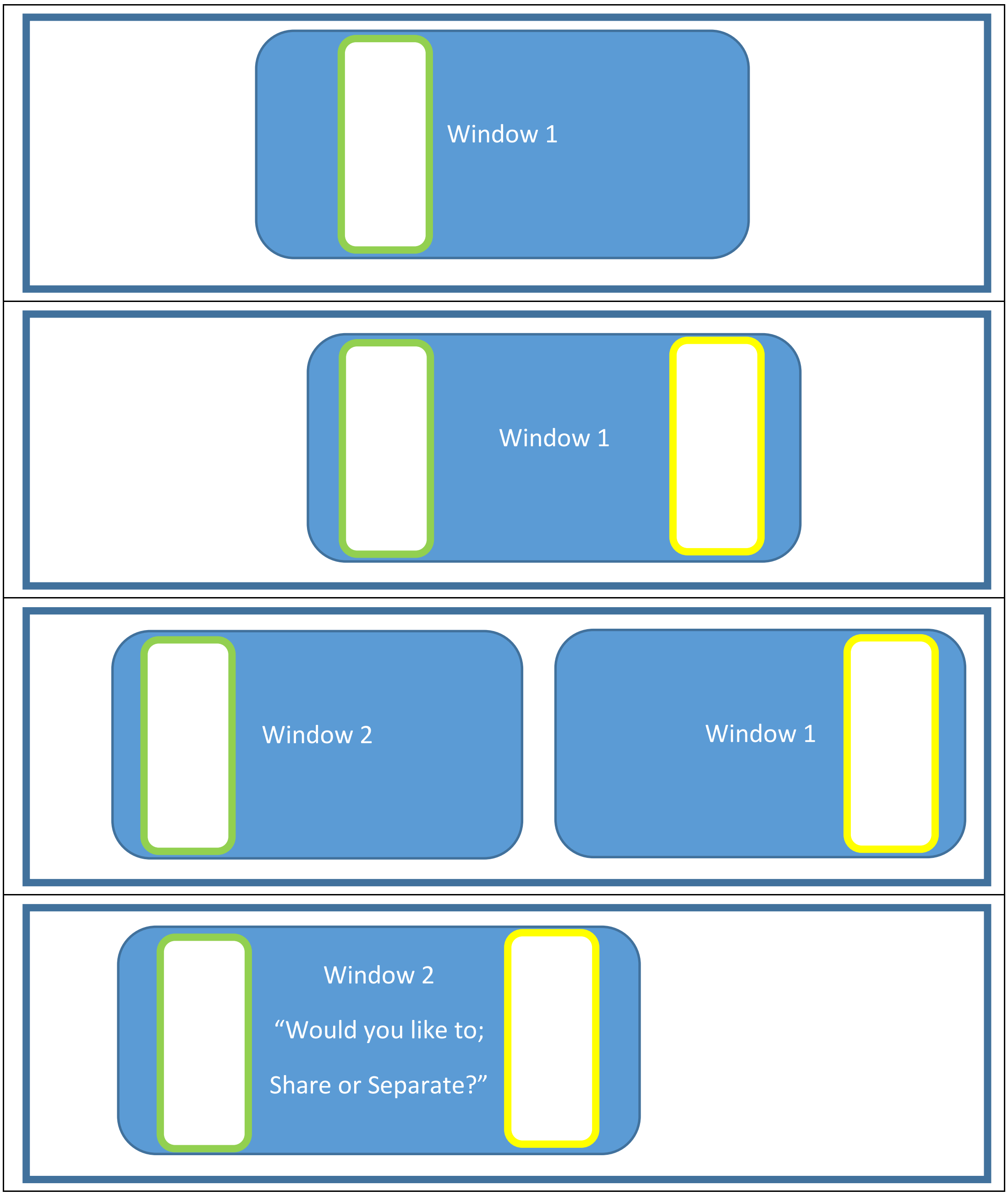


Questions: How do you feel about window re-size / positioning. How do you feel window size was related between the groups?

Supporting windows – Position to move groups / Introduction of new windows

- Main window with smaller supporting windows – Colour coding group / content.
- Adjust number of main windows – Position / size

One main window with central image, captions and supporting window. Introduce group with supporting window mid-way through. 1st group end of slides (supporting window disappears). New main window – new content with supporting window. Re-size first window. 1st window end of slides – window disappears. Form a new support window on new window ("Share or Separate" buttons).

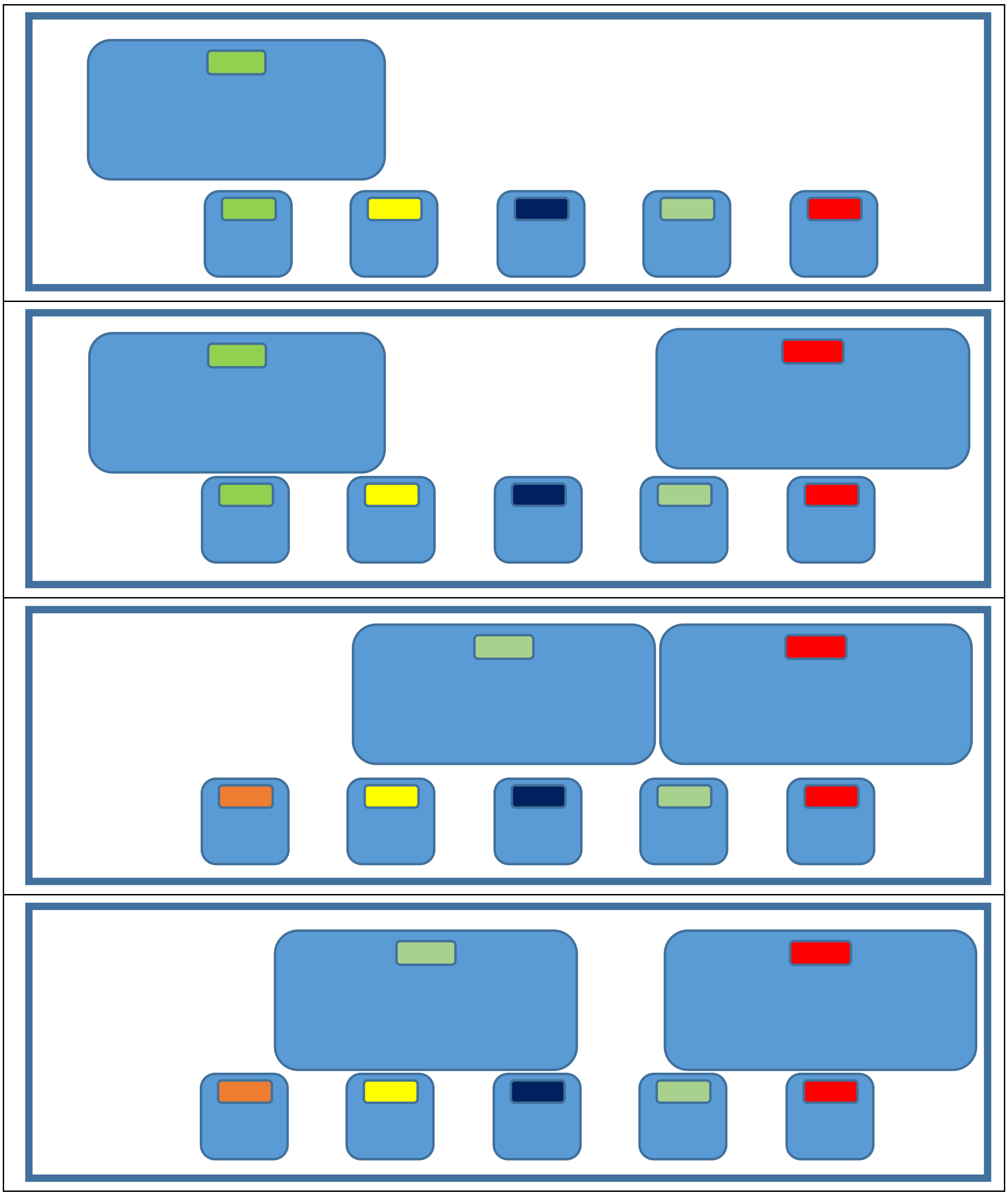


Questions: How did you feel about a group joining the window? Were you aware of the content of the other group? How did you feel about multiple groups using the same window? What was it like sharing the window?

Colour co-ordination - Content / new windows

- Multiple content windows with colour coding / Generate new windows
- Delivering themes to specific groups
- Multiple entry / exit – Changing entry proximity between groups – Movement

Several potential windows across base. Approach with “colour selection card”, display adapts to your needs. One group enters – adaptation. New group enters to “far away” window and adapts. First group leaves and gets a new “colour card” then re-enters. New window is next to current window. Windows adapt.

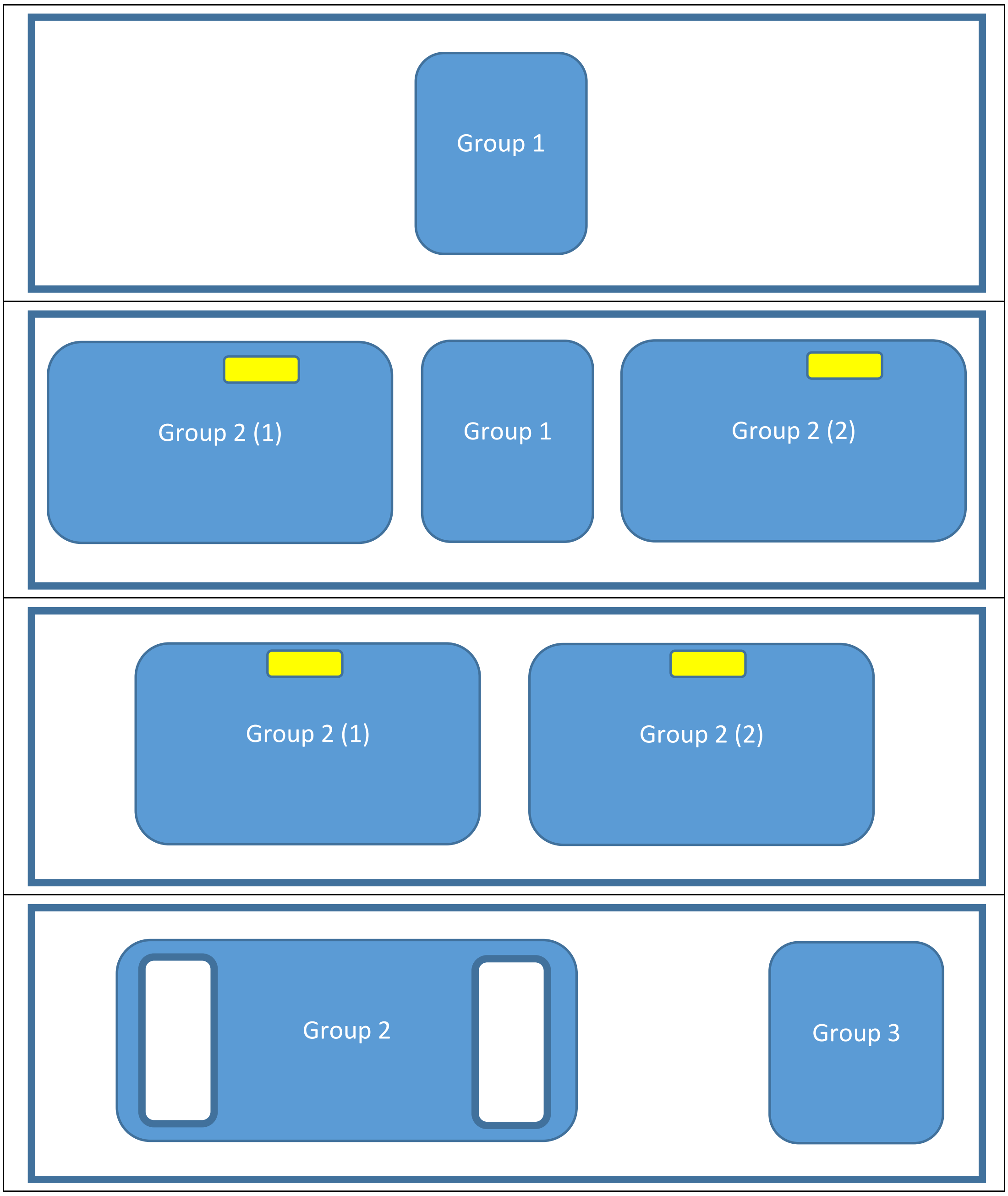


Questions: What was the relationship when new groups would enter? How should the adaptation work? How did you feel about the other users experience?

Separating groups – Multiple windows joining together

- Introduce a group while display is in use (central user position)
- Amalgamate windows after and re-introduce user – Movement and re-size

Single user at centre of the display. Introduce group (4) with 2 windows with indication of shared content. First user finishes and leave. Transition windows towards one another (higher detail), let group form together for one window when group starts talking (lower detail / supporting windows). Adapt window to allow single user to re-enter. (Consider sharing information between windows – Colour coding – supporting windows). Indicate to users the shared content between both windows.

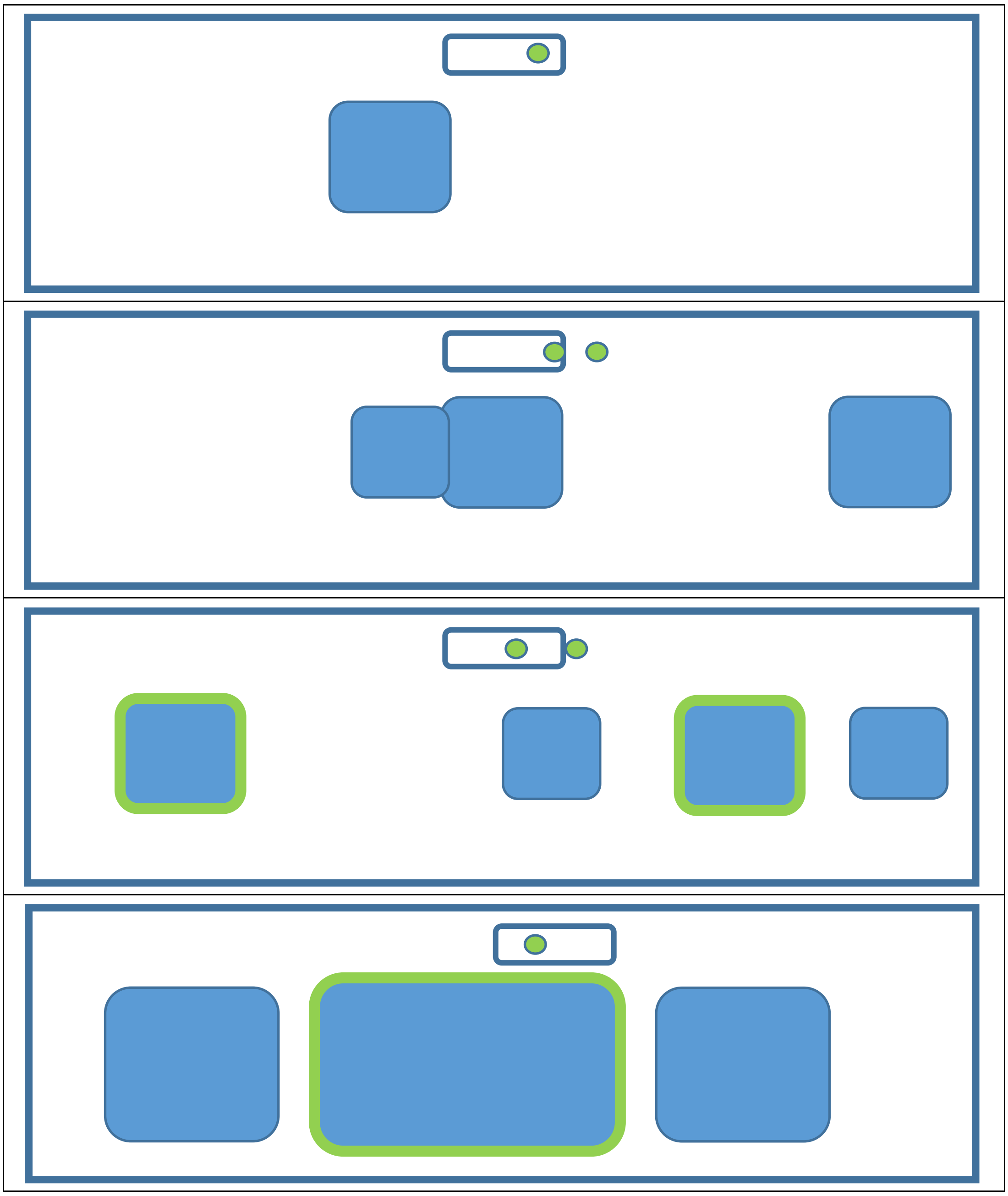


<u>Questions:</u> What should have happened? How did the amalgamation affect the experience, was it positive to join the windows? How did it feel to be sharing content – was this joining the experience or sharing content? What happened when there was a new user using the same content?

Indication of approach

- Adapt screen and spawn new window to show location
- Above window display of approach location
- Indicate to current users approach and adaptation

Introduce new group(s) (2) and adapt the windows with no warning. Indicate approach with expanding / contracting windows – How does it feel when the borders are adapting– green highlight for new window creation. Have above display indicator for approaching users.



Questions: Did an understanding of free location help or was it clear where the window would be? How did you feel when using the display to have approach groups indicated (above)? How did the adaptation help to identify ownership?

Transcripts

Study two – Transcript

Introduction:

The study was framed as an interactive display that would respond to group size and approach. Several members were already aware that this was not the case and that the display was driven by PowerPoint, however, this was not a problem and was not raised throughout the workshop. Of the several participants there seemed to be an eagerness to engage with the premise and people seemed genuinely interested in the workings of the supporting "system". However, of the remaining participants there were several who would not entertain the idea and did not seem eager to interact with the content in terms of a "smart controller" or "tailored experience". This concept had to be explained several times with a wider context created to support the idea of a tailored experience.

Key points:

- Describing the study as a series of interactive displays and organising the groups caused poor cohesion and a lack of understanding as to the nature of the adaptations.
- Several participants were eager to engage with the premise, however, several were not and this resulted in poor engagement with content and adaptation. The stand-off manner of interaction resulted in poor use of the space and limited movement and interaction.
- Participants were eager to see the "tailored" experiences, but were disappointed when the content did not relate to their interests, this caused boredom and separation from their windows resulting in poor usage and little response to adaptation.
- Direct interaction gave a better engagement with content as it seemed more tailored to the group's needs.

Study 1:

Description: This study initially supported one group in the centre of the display. The group did not form any cohesion but instead stood off from the display in a vague semi-circle – there was no real grouping to begin with, organising the groups did not create real groups. The second group were kept back until the system "indicated" they had been detected and they were invited to move forward. At this point the first window shifted to the left, however, Group 1 (G1) did not respond by moving, but instead shifted their vision to watch the content. This was in part due to their starting position which was removed from the display, this allowed them to remain still and observe the content. However, Group 2 (G2) were required to move around the central position adopted by G1 and ended up forming a diagonal line form the centre toward the extreme of the display. This meant that all members could see but were not in a prime viewing location to interact with the window.

After both separate content streams had ended there was an adaptation of both windows and the creation of a third offering questions about content from G1's experience. This was positioned centrally and resulted in both groups watching and laughing at what was being shown. Other than this there was little movement of any participant in relation to the separate windows other than the central window which had been explicitly selected for one participant i.e. you were in the centre so you were given a window.

After the study the location of the third window was the main topic. The location had caused confusion amongst participants as it was unclear who it was intended for, it was only due to direction that it was really used at all. This was commented on by the user of the third window who thought of it as a co-incidence that it was there at all, as well as G2, who mentioned the proximity to their window was distracting as it was not related to their content.

The second pointed asked directly to G2 was about their initial position and the formation of a line around G1. The main comment was that they did not want to intrude upon another group who were already having an experience, however, G1 had not made any effort to move as a result of the adaptation, or when they were aware that there was another group approaching. Still, G2 expressed very passive behaviour and were comfortable to observe the content from a distance.

When asked about the adaptation of the window G1 mentioned there did not seem to be a relationship between the adaptation and the approaching group, also that there was no indication that the window belonged to their group so they were unsure why the adaptation was taking place. They would have liked some understanding about why there was an adaptation or the upcoming interaction of the new group.

Key points:

- There was little cohesion in the groups leading to poor interactions around content windows / the display – groups did little to interact around the windows in a "coupled" manner, this resulted in a maximised use of space and a stand-off nature towards windows.
- Deliberately organising groups and offering them a personalised experience was difficult to generate a replication of what might be seen in a museum or gallery context.
- Approaching groups formed away from groups currently using the display as they did not want to intrude upon somebody else's experience.
- Positioning a window in the centre of the display was confusing to both groups and distracting to the group not directly interacting. There was no indication of ownership yet the position was equidistant to both windows. The user of the third window did not seem comfortable being singled out from their group and positioned away from the start location. It was only through direction to do so that the windows was used at all.
- When a second group approached there was little effort from the first group to move. They seemed content with their position and did not see a reason to adapt their behaviour. This was because there was no link between the approaching group and the adaptation or forming of a new window.

Case 1: Participants are split in to three groups before the trial ranging between 1-3 members. As each group enters the space an adaptation of the display is triggered to introduce a new window causing existing windows to be re-sized and positioned. This considers how adaptation influences approach behaviour as well as those at the display.

It was found that the first group did not approach the window or engage with content in a meaningful way, instead the group stood back to observe the display and content. As additional groups entered the first showed no response to the adaptation but continued to observe. This resulted in limited space for additional group approach and confusion over ownership. As the first window was removed from the display the first group did not change their behaviour but remained in the centre of the space. The findings can be described by;

- Group one saw no direct link to the first window as it appeared at the same time as they entered and this seemed normal. There was no feeling of being engaged with the system or being actively tracked.
- The size of group one (3) allowed them to each have a comfortable amount of space to observe the display, resulting in the group occupying most of the available space. This loose formation indicated group one were entitled to this space by later groups.
- As additional groups entered the first group did not notice their presence and so did not relate their entry with the adaptation.
- The second and third groups noticed upon entry that there was an adaptation and it was likely related to them, however, they did not want to interrupt the first group and so did not make a significant effort to engage with their content windows.

Considerations:

- The initial layout of content did little to draw the first group in to the space or encourage group formation to either side of the display. The small group size allowed for a wide distribution of users with little need to consider line of sight or personal space while initially engaging.
- The casual approach allowed the first group to observe all changes to the layout, and the initial lack of need in allowing other users line of sight persisted where the second and third groups maintained a removed position, having little impact to cause adjustment.
- While later entry identified the relationship to adaptation, the on-going interaction took precedence. Combined with the awareness of ownership found during the adaptation, shoulder surfing was not considered as this would apply social pressure towards content that was known not to be their point of focus.
- The large presentation of content and lack of feedback, ownership or direct mapping of the content windows to group entry limited the effectiveness of the adaptation. Users simply saw multiple pieces of content and did not respond to layout changes as social cues.

<u>Study 2:</u>

Description: Group 1 (G1) approached the display and stood back to observe the window positioned in the centre. The supporting windows with additional content was positioned below the window also in the centre. All three members were around 2 – 2.5 m away and did not stand close to one another. When Group 2 (G2) were introduced there was little movement of G1 during the adaption, resulting in G2 standing around 1 m behind G1 and wrapping around to the right hand side, where there was a little more space. After the adaptation there were two supporting windows to either side of the main window, these were bordered with each groups corresponding colours (Green and Yellow respectively), the position of these windows to the side of the main window, as well as the appearance and position of G2, caused a slight shift to the left hand (Green) side of the main windows from G1, however, this was limited to one member who moved and another who adjusted their position, the third remained in the centre of the window but stepped back to allow better line of sight for G2.

At the point of transition to a new window, G1 has begun to leave the display as the transition was not immediate or indicated to the group. This resulted in their viewing position being shifted towards the new window. As the initial main window had shifted to the right hand side, G2 were now in a better position to observe the content, however, one member did not approach the display, but instead remained at a removed position in order to observe both content streams.

When asked about the interaction the main response was that the interaction had been confusing. There was no understanding as to why the interaction had been shared between the two groups when G2 entered. When G2 approached there was an adaptation to include a second supporting window, however, this was not understood by either group and there was no understanding as to why the experience was being shared when there was such a large display, it could have been used to support the information across the whole display instead of a single smaller window.

Further to this, G1 did not understand that the information was being repeated for G2 as they had join midway through the experience. It was only after the information repeated itself after the adaptation that it was understood that the windows were looping.

When asked about the viewing of both windows content, it was noted that the transition speed of the content and resolution of the screen had allowed G2 to observe the content before interacting with the main window, this resulted in the repeated information not being of interest as it had already been seen and so the individual; decided to observe G1's window over their shoulder.

Finally, when given the option to split or share the window there was no member of either group who wanted to make the decision as it was felt that it would be encroaching upon others decisions. The consensus was that both groups would want to stay independent and did not want to share the windows, even though there was no concept of ownership over the window or content, however, it would be preferable to maintain the separation. Yet, no individual wanted to make the decision, especially without having to communicate to or between groups.

Key Points:

- Approach behaviour was very limited and saw groups stopping as soon as they were able to observe the content, perhaps as the result of poor group cohesion and a limited wanting to engage as a group. This resulted in further approaches being limited in space to observe or engage with the display at a distance that was comfortable for social interaction and not intruding upon the previous group.
- The adaptation and indication of ownership of a supporting window did little to move the groups, although there was a small amount of movement in respective directions. It seemed to be a problem for the groups to share the content window in this manner – why are they joining our window, although the groups were willing to move around and share. However, there was no real reason for anybody to move if they did not want to.
- Upon adaptation there was confusion as to why the window had been shared until content began to repeat – There had been no indication of an approaching group and poor understanding of the need / process of adaptation. There was also little

movement from groups as they were able to see all content from their starting positions.
- The centrally positioned user (G2) had already observed the content form the group before and so was bored of what was delivered. As such they stood back in order to observe both streams. There was little content delivered to any one individual or tailored for a group interest. This left users with little choice to be made other than to engage with what they were offered. Most of the time this was found boring.
- When offered a chance to split screens no one participant wanted to make the decision for the group, as they were unsure who should be sharing. The preference was found to be splitting the groups and having separate screens.

Case 2: The participants were split in to two groups and informed there would be specific content for each, but not told how this was indicated. The first group was allowed to enter and a yellow bordered window was used to indicate content in the centre of the display. As the second group entered, group one's content window moved to the left by 0.5m and the same content was shown, bordered in green, 0.5m to the right of the centre. After the content had finished the two windows merged and two buttons showing "split" or "share" were displayed. This considers how groups determine ownership and how this can imply group interactions and supporting behaviour.

It was found that the first group entered the space but did not approach their content directly. As group two entered there was no need for group one to move as they could read all content available. Again, group two did not want to encroach upon group one, and so remained behind and to the right of the groups position. There were several adjustments within group one as the second group was noticed, with individuals moving slightly to the left to allow better lines of sight for those behind and this had an effect throughout the group. The findings can be described by;

- The interaction was felt to be confusing as there was no clear link to any one piece of content and the two groups were unsure why they were having to share content.
- The adaptation and mapping of content to either group was not understood or clear during entry, so there was no need to approach directly or follow the adaptation.
- The option to split or share was confusing as no one member wanted to make the decision for the rest of the group. It was unclear why the groups would be merged together, but the consensus was that both groups would prefer to remain separate.

Considerations:

- There is a similar limitation in initial entry and formation behaviour due to the smaller group size. The new window adaptation upon second group entry encourages further approach and exploration of the space by the second group.
- The use of colour to explicitly show ownership to a second group encouraged further awareness of others in the space and had some impact upon the first group to search and increase their awareness leading to adjusting.

Merging of windows heightened the awareness between the groups and encouraged a shared focus, however, the shared experience was not appreciated by either group as both wanted to remain separate.

<u>**Study 3:**</u>

Description: This study required groups to select "cards" to interact with the system and so groups would line up to take turns interacting. The first group made little effort to interact directly with their content and instead stood back to observe from a distance. When the second group entered there was a clear separation of the group's positions given that both windows were at extreme positions of the display. G2, while standing back initially, had content that caused them to laugh, however, there was little to no reaction from G1 who were paying attention to their window which had very small presentation and required a level of focus to engage.

When the display did adapt (based on card interactions) there was a slight repositioning of G1 in relation to the starting and end position of the new window, although the adaptation was quite small relative to display size and group positions. However, the close proximity of the new window to the current position of G2 resulted in an adjustment from a G2 member. There was a shift backwards which allowed the participant to observe the content of both windows while remaining in a removed position.

When asked about the decision to move, the member of G2 commented that they were "bored" of their content. This is likely due to the slow scrolling nature of the windows and the lack of themes in content delivered to each group. As it was mentioned in the Introduction that each group would experience a tailored set of content in relation to their group, as well as the cards they had received. When it became apparent that the content was not tailored to the group the members quickly lost interest. It was also commented that the cards given out should have been selectable by the groups, so giving them choice over the content they could view. The use of coloured cards was considered a very useful mechanism for interaction and allowed a powerful mechanisms throughout the studies.

This use of cards was commented that groups could have split based on what was available and what individuals wanted to see. It should have been possible to select the cards and decide what content would be displayed, this could have then caused groups to split and new formations to form around appropriate windows. It was noted that it was unclear why cards were used to get an interaction within the group, or the relationship between ownership and the need for adaptation of new windows when all of the content could have been shown on screen, allowing for individuals to make their own decisions as to how to interact.

Key points:

- When presented with cards users found that they were more engaged with the content as it appeared to be more tailored and personal to their group. This resulted in groups remaining to their separate windows. This could have been related to the presentation of the content in each being fine requiring greater attention.
- When the separation was large the groups remained separate, however, when the windows were in close proximity there was a tendency from "bored" members to observe the content of the other group.
- The use of cards resulted in a more tangible interaction for users although it was mentioned that they would have liked to select the cards themselves. This would likely have resulted in fracturing of the groups as people separated to content they found interesting.

- By giving groups a direct relationship with windows there was more reason for interaction, however, a lack of interest in the content resulted in movement away to potentially find something more engaging.

Case 3: Participants were split in to three groups and given a card with a colour indicator on it. Each group was able to enter the space and show their card to the camera, this would correspond with the coloured content shown on the display to give the impression of generating a content window matching that colour. Once all groups were in the space the windows would begin to disappear and or adapt their positions. This sought to identify the relationship of interaction and selection with ownership and the influence during adaptation.

It was found that group one entered the space directly and approached their window and maintained a high level of focus, the content presentation was extremely detailed. As group two entered they also followed their window and engaged for a time. Group two began to lose interest with their content and did not follow the adaptation but instead engaged with the third window, which was created near their position, so preventing group three's interaction. When there was only a single window left the group adjusted their position to allow better access for others in the space. The findings can be described by;

- Group one found their content highly engaging and did not notice or attempt to engage with any other pieces of content until their window was removed.
- Group two quickly lost interest with their content and began to explore the display. This is likely due to the group being told the content was tailored to themselves, which quickly turned out not to be to their interest and so they sought a new article.
- Groups reported that content selection was extremely engaging and a powerful mechanism, however, they would have liked to select their own content type or have all content presented and form ad-hoc groups instead of being defined in their behaviour.
- Groups were unclear on why there was a need for cards or ownership of content and felt the experience would have been better if they were free to engage – it was noted at this point that the group were not following the grouping idea particularly closely and were treating the interactions as more of a free-for-all based on their lack of interest in the selected content.

Considerations:

- The more engaging "user selected" content along with smaller presentation encouraged direct approach and ownership to a window and the group remained fixed at this position.
- "User selection" also saw immediate dismissal of the interaction where the nature of the content was not found to be interesting. This separation from the interaction did not give a sense of ownership to the created window or to new windows shown for subsequent groups.
- Once the interaction of a group was broken they immediately reverted to exploration and took little notice of later groups entering or using the space, suggesting that recovery behaviour of the display and tighter coupling with feedback and ownership should be applied between "uninterested" and new groups.

<u>Study 4:</u>

Description: The initial user stood centrally yet back from the display. When group 2 entered they initially stood far back from the display behind G1, yet there was some separation of the group across the two windows. As G2 were so far back at the beginning of the adaptation there was no need to move when the windows merged on the left hand side of the screen. Movement was also difficult as G1 did not move quickly after their window disappeared. When the new window did appear for G1 it was to the right hand side of the display and not easily accessible for G1 as there were several people in the way. This resulted in some adjusting of position for several members, eventually leading to members of G2 positioned nearer the display moving slightly to the left whilst those further back not moving so as to observe both content windows across the display.

When discussing the adaptations G1 noted that there was little reason to move after the initial window had disappeared as there was nothing linking the new window to their experience. This resulted in them staying still after the adaptation as they were in a prime location to interact with both content streams as they saw fit.

As for G2, it was noted that the content was confusing, there was no indication of how to approach of use the separate windows, although the coloured indicators did help highlight that the content was the same there was still confusion as the oval shape had already been used to indicate the group had been "spotted" by the system. Despite the oval indicator linking the windows, it was noted that when the windows were separated it was simple to compare the content of both and realise that each was displaying the same. Although, there was confusion as to the position of the two windows and why they were not in relation to the approaching group and it was felt that the system should indicate the ownership and relate the position of each window to the separate groups. This was further highlighted during the adaptation when G1 could not be sure as to who was in their group and did not follow the adapting window as there was nothing confirming their ownership over the window or content. This was likely due to the closeness of the colours used to indicate ownership, which was picked up on by most participants.

G2 had a slightly stronger response to the adaptation and there was some movement of members to better viewing positions, however, it was noted that there were too many windows on screen, particularly the supporting windows which were confusing given that they were duplicating information, yet it was difficult to take all of this in when standing in close proximity to the display. This group also indicated that the colours were not clear and the layout was similar to that already seen in the previous study, were two groups were able to interact with the same content. In this case it was duplicated for one group, yet the layout and approximate closeness of colours used made it difficult to be sure. It was also mentioned that when creating windows there should be a very clear indicator of ownership, as well as attractors to the groups i.e. to indicate that there is a relationship between their behaviour and where they should / are able to interacting. This can be done with representations of sensor data, images of the participants or mirrors of their behaviour.

Finally, the content windows should not simply stop displaying and disappear as this is confusing and users are then left unsure as to what or where to go next. This resulted in G1 standing in the middle of the display and not understanding the nature of the adaptation for G2 going on around them. By standing in the middle G1 was then unsure as to which group they belonged to and where their content stream was. As there was no consistency in the group's members were unsure who they "could" speak with and which windows to interact around. It was noted that if left to form their own groups participants would likely have moved off to whichever window they found most interesting and formed independent groups around these.

Key points:

- The initial position of an on-going user is crucial in the approach of further groups. This seems to be independent of the respective group sizes. However, when offered mirrored content, larger groups will split in order to approach closer to the display.
- Without clear indication of the end of content or the nature of the adaptation there is no reason for movement. The adaptation of the two windows (G2) caused some movement, but G1 was still in position and resulted in confusion as to group membership and the windows available for interaction.
- Indication of ownership was confusing, as was the number of windows and display of content after adaptation. Ownership must be clearly indicated and new windows should relate to group behaviour.
- The two supporting windows were confusing to the group as they duplicated information. At close proximity it was difficult to differentiate the difference and resulted in being distracting. It was also confusing that this layout had been used previously for two separate groups to interact and the colours used were very similar, so causing further confusion over ownership.
- Window content should not simply stop, as users are left in confusion as to what to do next. Especially if there is some form of adaptation taking place as a result. This resulted in users being stranded and confused as to the nature of the adaptation and where to be next, leaving them in the middle of a second group.

Case 4: A single participants was presented with a narrow window at the centre of the display. The remaining participants were able to enter but given two separate windows on either side of the single user, with both using a colour indicator to show that both windows had the same content and ownership to the approaching group. After a period of time the single user's window would vanish and both remaining windows would merge in the centre of the display. Finally this window would adapt to the left and a new window would be shown in the gap created on the right side. This sought to identify how a single group might behave around an on-going interaction by a single user and how they might respond to adaptation attempting to manage the space.

The single user did not approach the display directly, but stood in the middle of the interaction space. As group two entered, the participants did not want to pass this location and instead stood behind and around their position, with a slight leaning towards their separate window locations to the left and right hand sides. When the first window was removed the single user did not know what to do and ended up trapped between the two parts of group. This then prevented group two from moving with the window adaptation due to the presence of the single user. The findings can be described by;

- The single users' initial location presented confusion for the approaching group. The second group was able to quickly identify that both windows contained the same information, but the configuration of windows did not help with approach. Instead the group remained at the back and observed both windows separately.
- Not clearly indicating how or where to interact left both groups confused, especially the single user when their content window disappeared. Both groups were unsure

of how to move or interact with the adaptation due to isolation and encroaching on space respectively.

Considerations:

- Without any immediate consideration of other users entering the space or how it may be divided the individual users adopted a neutral position. This affected the second groups' entry but there was no feedback or mechanism for the individual to exit the centre space.

Removing the first window entirely left the individual with no reference point to the display in their expected behaviour. With the secondary windows merging in the centre and the secondary group behind there is not clear feedback to move or path for retreat.

Study 5:

Description: The intention of this study was to have the groups break down in to individual / pairwise interactions and have a large number of people pass through in rapid succession for multiple experiences. During these experiences there were a range of adaptations that would indicate there were other groups approaching as well as an indicator as to the location of the new window on the screen above the content windows.

During the set up for each individual there was too long of a transition between the entry points for each window. This resulted in several individuals approaching the display separately and attempting to interact with the content over the shoulders of earlier groups. This also resulted in the participants missing the indicators of window position and crowding around the display. As a result of the spread out nature of all participants there was no direct engagement with any one window, as such the indicators to approaching groups was missed as all of the indicators were seen by most participants and any underlying meaning was lost.

In feedback, the crowding resulted in any direct interaction or ownership of windows being lost, further to this there was no direct relationship between the actual content shown towards each participant. As for window ownership is was noted that an indicator (colour / participant picture) would have been useful for indicating to participants who should be where. There was a clear need for indication of "personal experiences" – several options included feeding sensor data back to participants or following movements with content windows. There were also considerations of the direction of viewing for each participant as this would only enable one group to view the content properly and would discourage viewing by other groups.

During the interactions there was a large amount of confusion as to the meaning of the adaptations, particularly as there were several different approaches to indicating approach. While participants could not gain any understanding of the nature of the adaptations, a key point was that there was no need for any indication at all of approaching groups as there was no subsequent adaptation of their content window, so any warning of approach was not required – "It doesn't affect me".

Further points highlighted the need for several small windows when the display could support one large piece of content. There were also no considerations of scaling the content to the number of people or their position in relation to the display. There were comments in regards a stronger feedback of adaptation and window ownership back in to the real world, such as interaction and approach behaviour for creation and adaptation of windows as users were finding themselves getting lost in the behaviours of the system and having a low tolerance of slow or un-coordinated response. However, it was noted that content delivered to the user instead of having to move to the content was definitely a bonus and made sense in terms of multiple interactions taking place simultaneously.

Key points:

- Without clear direction or acknowledgement individuals will quickly approach the display and crowd around. As there was no direct link to any one individual the interactions with the windows were extremely limited resulting in a large group observing several windows at once.
- There was no understanding of the adaptation of window surrounds to indicate approach. It was also noted that if there is no adaptation then there is no need to have this information indicated as it proves to be a distracting.
- In terms of delivering a personal experience there needed to be a direct relationship between each user and a content window, either through colour, tracking or image of the user. This would have ensured user knew where to be and would have focussed more on the content delivered.
- It was noted that a large display should have a single large piece of content. The use for multiple single pieces did not make sense, however, it was noted that having content come to the user or group was a nice addition and made sense in a large display context.
- The system required much higher levels of feedback as users found themselves becoming lost in the adaptations and unsure of the action / reaction that was taking place. Users had a very low tolerance for this behaviour and were frustrated when they could not understand or get what they expected from the interaction.

Case 5: It was found that the users entered quickly and paid little attention to any of the adaptations. All groups entered the space quickly and congregated around a single window without time for additional windows to be created. This resulted in no one group achieving ownership of a single window, but instead all users engaging with all content.

Adaptations were not thought to be related to any behaviour, but it was reported that windows should have a stronger relationship with group position and stronger feedback around adaptation and potential interaction types.

Summary

Study two Conclusion

Organising groups did not create a natural group dynamic, this resulted in poor engagement with content windows and a reluctance to be too close to one another within the space. Separate groups would keep to themselves to some extent, but when group members were later mixed there was confusion as to who was a member of each. These groups would spread out as there was no desire to be too close to one another (people were unknown to each other), this meant that space was poorly used and further groups could not enter the space easily.

Poor engagement with content and group resulted in adaptation being ignored as there was no obvious reason as to why there was an adaptation. When there was no obvious reason the use or relation to approaching groups of adaptation was confusing and distracting from content.

Participants were eager to experience an “adaptive / interactive” display, particularly elements of personalised or tailored experiences. However, when there was poor content delivery i.e. not interested, the experience was broken. The focus should not have been on content delivery, but instead a personal window for content to be shown - There should be some consideration of an overarching context, or themes that can be selected for a personal experience.

Direct interaction (using cards) proved much more effective / engaging for users – There was a preference to be able to select the cards instead of being given them as this would have allowed for more fine grained control and selection of appropriate content. It was also noted that “groups” (as selected) would have been likely to have fractured to engage with their preferred content. This would have resulted in natural groupings being formed.

New groups entering the space did not want to intrude upon groups already interacting, irrelevant of the size of either group or their current position. A lack of space, caused by expansive groups, resulted in limited approaches for new groups, and as adaptation was not linked in to the approach of a new group there was little understanding or reason for existing groups to move. New groups would stop behind previous groups as soon as they were able to observe the content, this may have been either content window as there was little understanding of ownership, although adaptation did cause some motion and new windows could be partially observed when spawned, there was a lot of line of sight being blocked by previous groups spreading out.

A window in the centre of the display was distracting for both groups and caused the person using it to be singled out (after being directed to use it). There was no sense of ownership over the window and the position in the centre of both existing groups caused it to be a distraction. More to group 2, as the content had no relation to what they were viewing. When asked to make a decision about the layout users did not want to step up and be the one making decisions that would affect other users. They were unsure as to who they would be affecting and what this would do for others interactions.

Group joining “personal / group” content windows seemed to be a problem and the duplication of content over personal supporting windows was a distraction. The use of colour indicated ownership, but the colours were very similar causing confusion. The duplication did not help and there was wonder as to why the whole screen was not used and why both groups were so close together.

Groups sharing content was not beneficial until there was an understanding of the repeating nature of the content, however, this was not clearly conveyed at the beginning of the interaction and so caused initial problems. Groups were willing to share windows and content, however, there needed to be a strong reasoning for this and it had to be understood by both groups before the interaction started.

Users would observe the interactions of other groups from a distance, this resulted in repeated content being boring and so limiting the level of engagement. When this happened the “bored” users would move away to observe other content to find something more suited. If content had been tailored to groups or individuals then there would have been more inclination to interact directly and not wander off when old / boring content was repeated. This was more pronounced when windows were in close proximity and bored users could simply look over at what was on windows. When there was a larger separation bored users would step back so as to be able to see a larger portion of the display.

If users had the option to display whatever content they were interested in there would have been more dynamic behaviours around the display, this would also have resulted in new groups forming around content that was found interesting. Alternatively, several windows all being displayed could have adapted to the actual interaction of users proximity and orientation to each window separately i.e. the most popular would get larger, so grouping people as they wanted.

Approach of new groups was dependant on the position of current interactions, regardless of respective group sizes. It was also possible for larger groups to be divided over several smaller windows if the space was not available for one, based on duplication of content, which was understood as the windows had a large separation and mirrored content, however, coloured indicators did little to help highlight the duplication as they were a similar shape to those used to indicate a new user group had been detected. The idea of ownership was confusing and should be clearly highlighted, otherwise there is confusion as to the adaptation and what is expected. It is also the case that adaptation should mirror group behaviour or should clearly indicate why there is a need for movement.

The end of a content stream should be clearly indicated, otherwise users are unsure about what to do or where to move. Without clear direction they will feel lost which results in confusion as to group membership and crowding of by new groups entering.

Duplication of supporting content should not be in close proximity as it is difficult to determine the content at such close proximity and results in distraction.

Without clear direction or acknowledgement users will simply approach the display as they can and find space to interact. Without clear direction or indication of ownership users will be quickly confused as to ownership of windows and will resort to a wider view to observe as much content as possible. Adaptations and indication of approach are not easily understood when they are in close proximity with no clear link to meaning. The indication of information is not necessary if there is not going to be any change, there is no need for the user to know if there will be no adaptation.

If the aim is to deliver a personal experience then the windows should be closely tied to a user, otherwise there is mass confusion and it is difficult to create engagement / understanding from adaptation and content delivery. The system should provide much higher levels of feedback as users have a low tolerance for confusion and they will simply ignore the indication / adaptation or leave.

A large display should have a large piece of content. It does not make sense to only present small windows on a large display, especially when the content is mirrored.

Key points:

- Groups should not be organised for the studies, but should be allowed to form naturally. This will ensure accurate behaviour of the individuals and resulting group.
- Adaptation should have a purpose and be used when there is good engagement of the group, otherwise meaning is lost and the adaptation becomes confusing.

- Users enjoy a tailored experience, but this must meet expectations. Alternatively an overarching content theme and reason for interaction are required.
- Direct interaction was enjoyed, however, this needed to allow groups to select their content. Multiple available content streams would have resulted in natural group formations.
- New groups did not want to interrupt another group already involved in an interaction. Without knowledge of ownership a new group will approach to a minimum interaction threshold where they can see and will wait there.
- Window position is crucial as they can be distracting. Ownership becomes very confusing and separate windows singles people out when removed from the group.
- Individuals do not want to make decisions that might affect others, this singles them out.
- Groups were not comfortable sharing / having a new group join unless there was a clear need, the duplication of supporting windows on a small window was confusing.
- Colour affords an understanding of ownership but similar colours are difficult to interpret.
- Users who were waiting would observe previous content and would end up bored when they were then shown the same thing. This caused them to move away from their group and seek to find more interesting material.
- Approaching groups are willing to split if there is already somebody interacting and they can see they are being provided with duplicated information.
- It is easier to assess duplicated windows from a distance and make a decision.
- Indicators of ownership must be clear and cause no confusion between “system” indicators.
- Adaptation should mirror group behaviour, or clearly indicate why there is a need for adaptation.
- The end of a content stream should be clearly indicated, otherwise users are left unsure what to do next, particularly when there is an adaptation taking place around them.
- Proximity of windows is critical as there is confusion as to the nature of content.
- Without clear direction or understanding of ownership users will quickly crowd around the display. Most will take a wide angle view to gather as much information as possible.
- The system should provide much higher levels of feedback to keep users sure of actions and reactions, otherwise there is a low tolerance for error resulting in confusion and annoyance.
- If personal windows are used to deliver content to the user there must be a strong sense of ownership and feedback of this fact.
- Large displays should be used for large content, there is confusion when a display is used for small windows particularly with duplicated content.

B3 Trial 2

Layouts

User study layouts

Factors affecting interaction

User factors

- Position
- Orientation
- Awareness
- Focus

Display factors

- Position of window
- Density of content
- Presentation
- Ownership
- Size of window
- Supporting windows

While the factors affecting the display layout will indicate the effect on a groups formation, the interesting factors will be those of the individual in how they perceive the layout and then decide on how to interact given the current group formation. Understanding individual behaviour and decision making will prove hard as feedback is through reporting and recorded actions.

Organising groups

Groups will be constructed at the beginning of each study by assigning a card with a preferred content colour. There will only ever be a maximum of two group (blue / red) for each study, however, some of these cards may contain indicators to switch groups part way through, in order to encourage types of adaptation or interactions between multiple groups around windows.

Creating adaptations

Given the simple nature of the adaptations and content that will be displayed it should be possible to construct the interactions in a similar manner to the previous studies, where a series of PowerPoint slides are constructed with a pre-defined set of transitions. In the event that there is an alternate behaviour observed it should be possible to “pause” the study in order to ask the participants further questions and make real time adjustments to the layout of the slide show based on the groups perception of the interaction. The effectiveness of these can be assessed with participants in real time before the study continues.

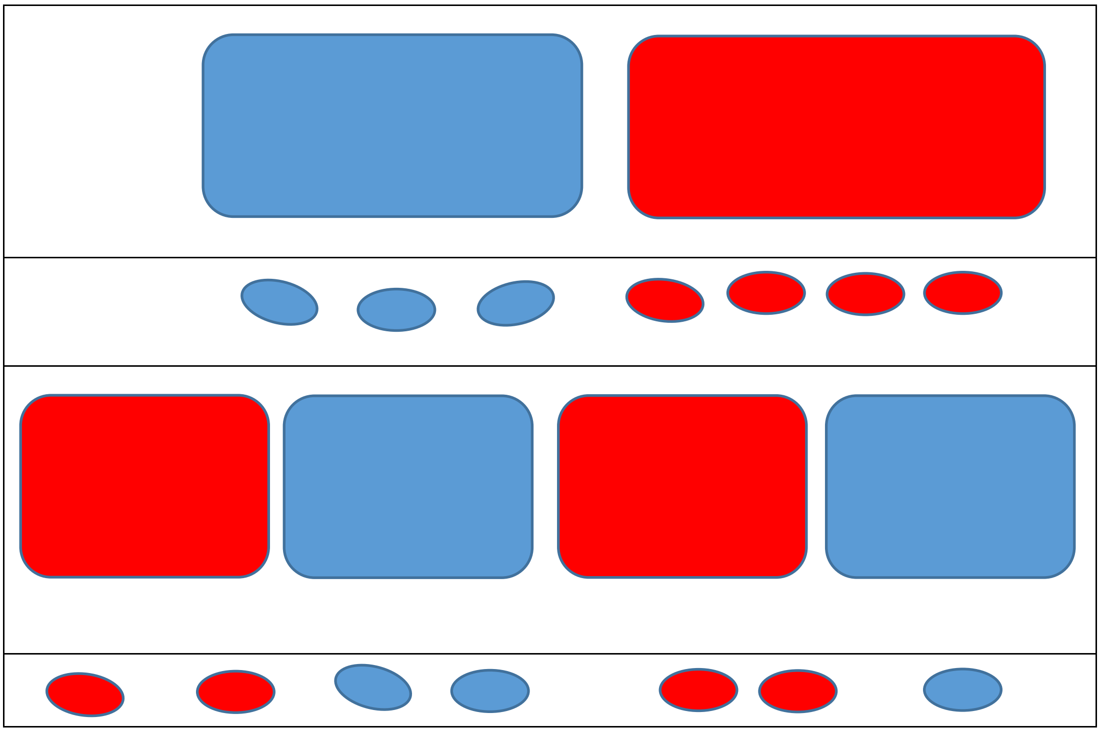
Slides will be made up of static content and so triggering transitions by clicks should allow more accuracy in responding to on-going behaviour, this will prevent breaking the interaction by minimising the PowerPoint and manually adjusting the layout. Further to this, by using much higher number of slides will allow for much finer control of adaptations. If the on-going adaptations do not match it should then be very quick to find the break in interaction/adaptation and make changes.

Study 1

Initially two distinct groups (red / blue) will form at separate windows with (3 / 4) members respectively. After a given time an additional red and blue window will form at opposite end of the display, resulting in the on-going windows being reduced in size. This will limit the number of people who can interact around each windows, in particular blue as there are more members and may encourage changes in formation or the group fragmenting over several windows.

This will investigate;

- Size and Position of windows
  - The relative size of windows to the group and their viewing position
- Density of multiple Groups / Windows
  - As there are multiple groups in close proximity it will be interesting to see how the groups handle their position and orientation
- Awareness of multiple windows
  - There would be multiple points for each group to interact. This would allow groups to split over several windows if crowding became a problem but only if they were seen.

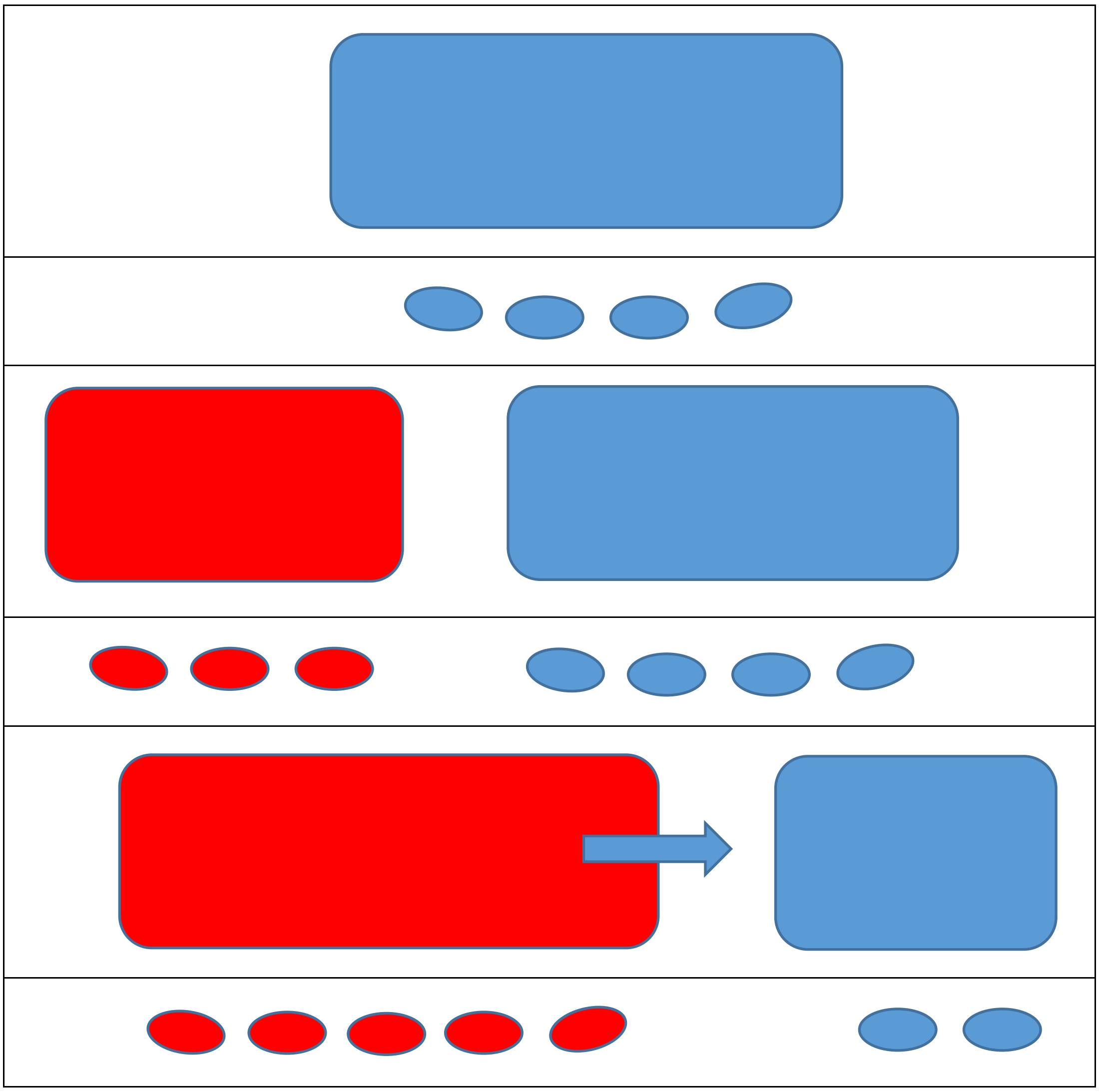


After the adaptation the groups will be forced to adjust position given the decreased window size. With the adjustment it is expected that the groups awareness will increase and allow them to see multiple new windows. If the decrease in space is significant it may be that the group fragments over multiple windows in order to have a more comfortable interaction. This would be the result of personal preference and would raise some interesting points in terms of group organisation and decision making.

Study 2

A large group (blue) composed of 4 members has access to a large window. After a time a second group (red) made up of 3 members enters the space. As the group enters a window is created for them causing a slight reduction and re-position of the blue window. 2 members of blue group will be given instructions prior to the study to join red window, causing a change in group size (2 / 5) respectively. As the members join the red window the size will increase causing blue window to shrink and translate to the right extreme of the display. This will investigate;

- Position and Orientation relative to a changing window size.
  - As the window adapts the central viewing position will move. This will be interesting to indicate where the ideal viewing positions.
- Awareness - New groups / Window adaptation
  - As there is an adaptation as the result of a new window it will be interesting to investigate how the on-going group feels about being displaced.
- Size of window relative to group size
  - As the window (blue) reduces the group will begin to move to (red), this will cause red to increase in size relative to the number of people.



The starting position of the window will likely result in the first group positioning in the centre of the display. As the second group approaches the first will not move if they are still able to view the content from their current position (Position, Orientation, Awareness, Focus). However, members in the extreme left position will likely have to move around the group, unless the entire group adjusts to allow them a position.

Initially the new window may not be red, but instead only indicate a new window. Once this turns red the new group may approach and the two members of blue group can also alter their interaction. This will highlight the awareness of changes across windows form their position.

By having multiple groups (red) (blue) approaching the red window separately this could create tension around the concept of ownership, so raising questions about how the groups negotiate the formation about the window.

- The starting position of each member will be interesting to investigate what can be seen and how their reaction is determined – In relation to the new group or adjustment in their window position.
- By having the red window expand towards the approaching members of blue group this will indicate there is a reaction to their behaviour i.e. the number of members using the window.

Study 3

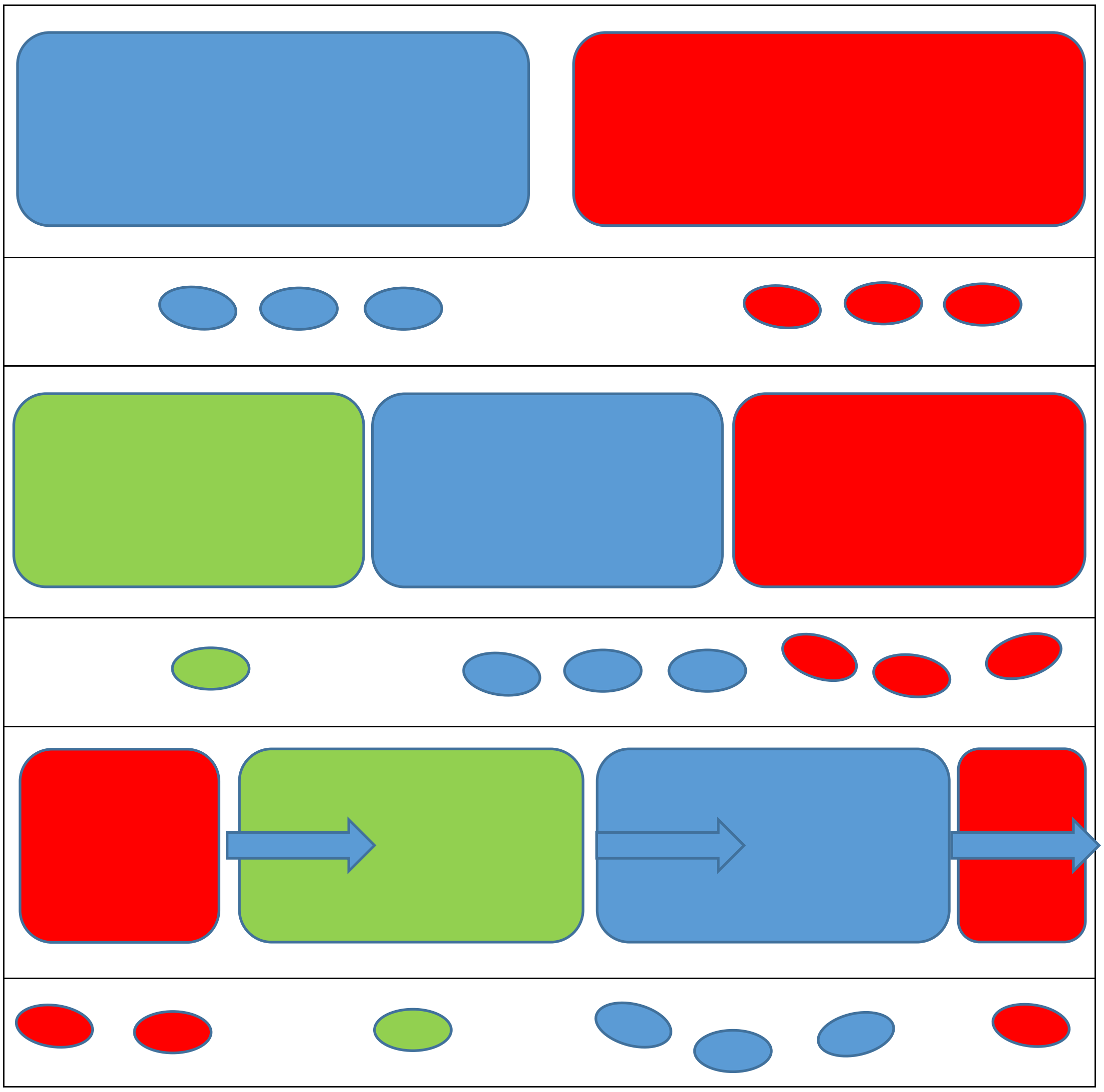
Two groups will start at the display (blue) with 3 members, and (red) with 4 members. Both will have windows of the same size. Participants will be random selected in to groups by giving them cards defining their preferred content interest. After a short time a new window (green) will appear, this window will not feature any interact-able content, but instead will be a place marker indicating the number of people that would be interacting with it (this could be silhouettes or a counter). In time this will increase causing the two windows (blue / red) to transition to the right and reduce in size.

After another time period a fourth window (red 2) will appear on the left hand end and expand in size. This will cause a transition of the (green / blue) windows to the right, while the on-going red window will reduce in size. If participants of the red window have an awareness of the new window (red 2) they may choose to interact with it given the limited space at the original window (red). If all participants move this window will be removed and all other will adjust position to the right.

This will investigate;

- Position and orientation relative to a changing window size.
    - As the windows adapt participants in extreme positions will have to move to be able to access the content, this will indicate ideal positions for interaction
- Awareness - New groups / Window adaptation
    - New windows forming will cause adaptation but the groups awareness of the reason will prove interesting. Also, the creation of an alternative interaction for (red).
- Size of window relative to group size.
    - As size decreases the number of people that can be supported will reduce. As the group begins to split from the shrinking windows this will indicate viewing comfort.
- Ownership related to on-going experience and new window formation.

- How a group feels in relation to having their window shrink and moving due to another groups adaptation. Also the inclusion of a second available window.



The multiple windows will likely cause distinct groups at the display where there is no need for intra-group interaction as there should be comfortable space between each.

During adaptation these groups will be forced to move closer together as well as have to negotiate how the group is organised around the display. The interactions and decision making of each members will be interesting in relation to the layout of each window, as well as how the two groups organise between one another.

As there is a second window for the red group there is potential for the group to entirely separate due to limited space. In this case blue group will have more space to adjust their position based on their current formation which may not be an ideal size for the number of members.

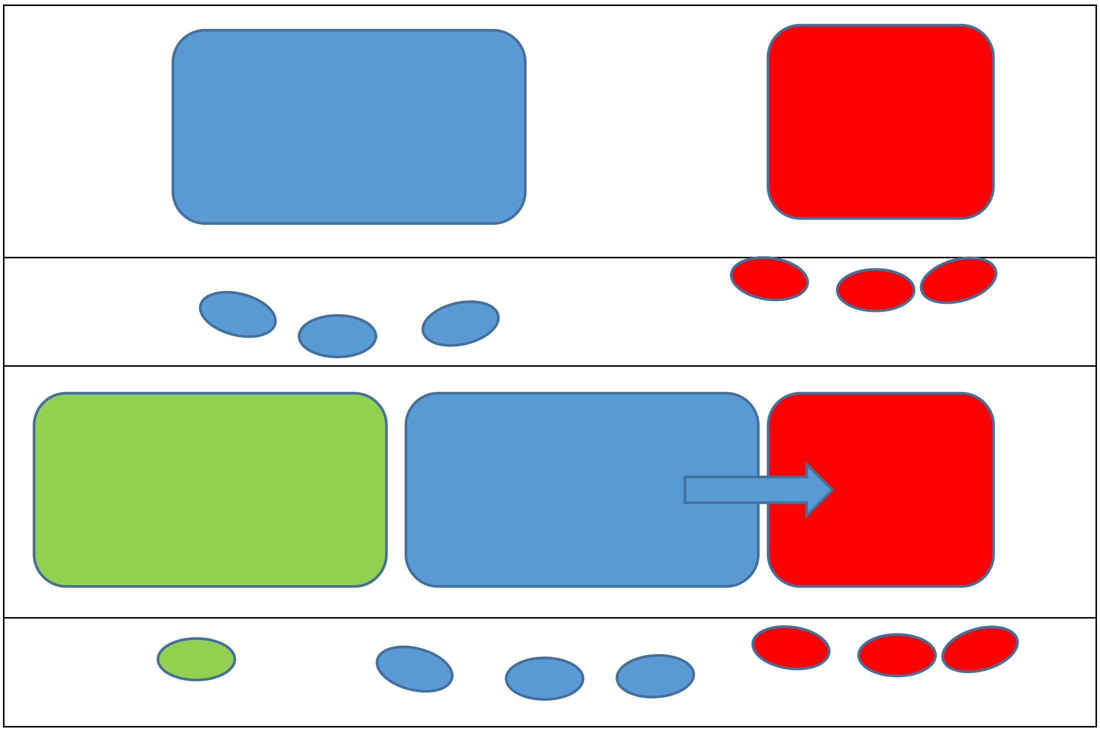
- As the windows adapt the change in position of each member will be interesting relative to starting position and window position, alternatively the way in which the members orientate themselves during and after adaptations.

- The groups awareness of new windows, as well as reasoning for why there are adaptations
- As the windows change size it will be interesting to note how the group affected responds i.e. if the size decreases does the group move away, and if so how many move.
- The way that groups feel about an on-going experience being interrupted by another group entering the space.

Study 4

The first group (red) with 3 members will be given extremely small text in order to encourage close proximity to the display. Once the group are in this position these will be a new window produced (green) with 1 member. This will cause a translation of (blue) 3 members towards the red window such that they are in extremely close proximity. This will investigate;

- Presentation
  - Small presentation (font) may cause high levels of engagement i.e. extreme proximity to the display. This may cause reflexive movement.
- Focus / Awareness of other groups
  - As the on-going group should be highly focussed, their awareness of approaching groups and adaptation may be lower.
- Position relative to windows and other groups
  - As the adaptation will force two groups into close proximity it will be interesting to investigate which group concedes the ideal positon.



Initially the separation will allow both groups to form separate formations, yet as the adaptation takes place red may not be aware of the approaching group. This will identify their awareness in relation to their position at the window.

As blue group moves towards red they will be limited in how they can approach the group and maintain their formation given that red are already at the display. This may result in them taking a removed position from the display or interacting directly with red in order to manage the arrangement.

The window sizes have been deliberately set as disproportionate in order to raise questions about how content is delivered. If groups make a note of the difference in group size, as well as the position of the red window this could lead to some interesting points about how participants use the different sized displays i.e. single user at a large window (green) vs. 3 participants at a small window (red).

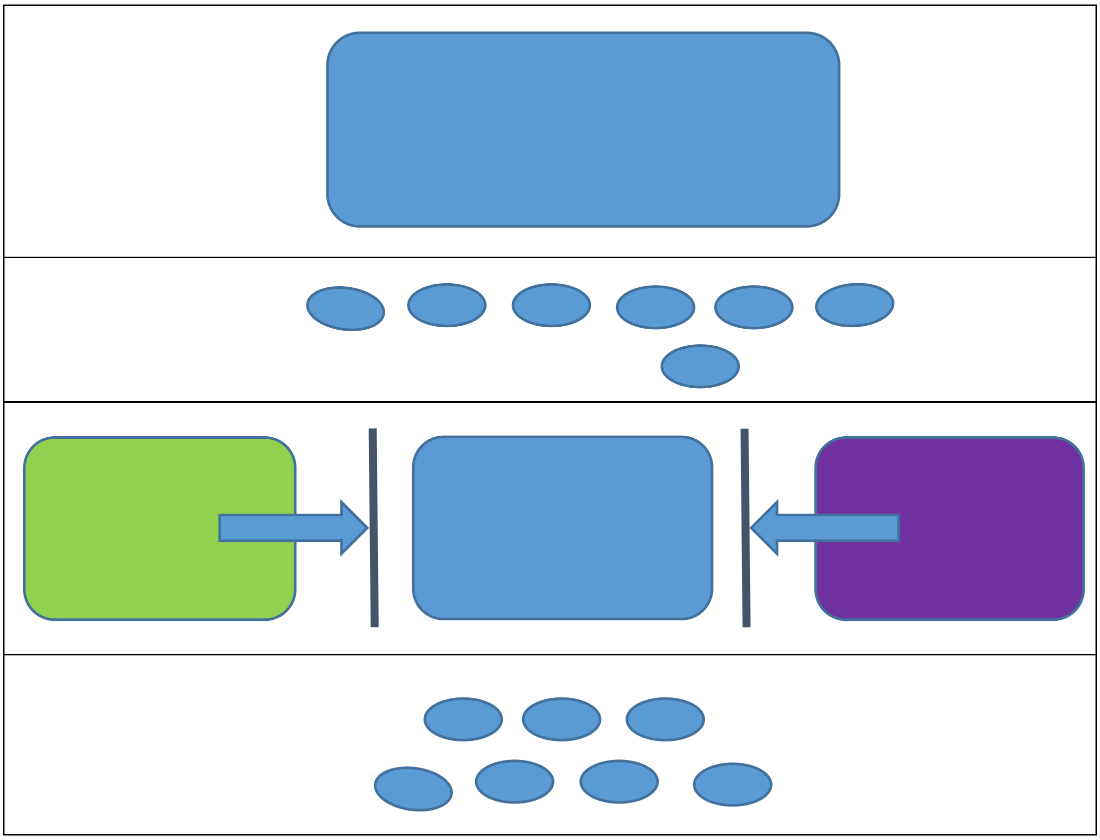
- There will be focus on how presentation affects formation of the group (red) and how this changes their awareness of other groups and adaptations.
- There will also be consideration of how blue views the on-going red interaction and their resulting formation. It will also be interesting to consider how blue views green and the difference in the size of windows, as well as the impact of the adaptation.
- The position and orientation of each member of blue as the result of multiple windows either side of their position. Will the adaptation result in movement or simply a change in awareness.

Study 5

A large central group will be interacting in the centre of the display (blue) composed of all 7 participants. As multiple other groups approach from either side (purple / green – no members in these groups) their space will be compressed, causing the group formation to have to change. As the window gets extremely small there will be an indication that the window will not shrink any further. The window will then be able to expand again to allow the group to return to their preferred formation.

This will investigate;

- Awareness of new groups / windows
    - As there will only be one large group the formation about the window may limit the awareness of the group to new windows.
- Size of window to group during adaptation
    - The window will be reduced to make interaction for a large group extremely difficult. It will be interesting to see how the group responds.



Having multiple new windows form either side will cause a change in the central position of the window possibly resulting in the group having to adjust their position in order to maintain the interaction. This will draw interesting factors relating to the group starting formation and position of the window during adaptation as well as how on-going interactions are handled based on position.

- The starting position will affect how an individual can observe the content, as well as any need to adjust position based on the group formation.
- Individual decisions to continue interaction with the content may also become a factor.

Transcripts

User Study report

Introduction

This user study was informed by a series of workshops carried out to investigate how groups and individuals would interact around a display with adaptive content. These initial workshops found factors of the adaptations which would influence the user experience. The key finding highlighted factors of both the display adaptations and the users behaviours, these included;

- Display:
  - Position of Windows
  - Size of Windows
  - Presentation of Content
  - Ownership of Windows
  - Density of Content
  - Supporting Windows
- Users:
  - Position
  - Orientation
  - Awareness – Of changes to the display and social interaction
  - Focus – The object and level of Focus

This user study was designed to test several combinations of factors relating to the display and the effects of this would be observed through individual responses of the users. The study was made up of four separate trials, each of which investigated different factors of the display (the details of each can be found in the "Design of the User Study" document in the appendix). The aim was to run the study with seven participants, who would be given instructions at the beginning of each trial for how to interact with the range of content presented. These instructions were limited to "ownership" or group interest in particular content windows which had coloured borders.

The study was run three separate times in order to highlight the differences resulting from social interaction and individual behaviours relating to engagement with content. The session were video recorded and a post session discussion was held to determine the reasoning for participants behaviours after each trial, with a final discussion to cover the whole experience and cover more general points about adaptive displays.

Results

Each trial was run with the same parameters for the separate studies. This allows comparison of behaviours between the trials to highlight the consistent and individualistic behaviours resulting from the group formations and adaptation of the display layout.

The aim in these studies had been to evaluate the individual responses of participants based on the factors stated above. There were considerations of groups within the study, however, the intention was to direct participants between content with some understanding of their underlying motivations. The observed behaviours would then inform the more subtle actions relating to personality and social interaction.

It should be noted that a portion of Study 2 data was lost, which reduces the richness of response.

Trial 1

This trial had the group split into separate teams of Red and Blue, relating to the ownership of the windows. At a given time two additional content windows would appear in a staggered patterns across the display. This was intended to cause the maximum amount of movement across the width of the display to highlight the most common mechanisms of social mediation during movement.

This investigated; Awareness across the display and perceived ownership of physical space relative to the display layout.

What was seen;

Study 1:

- Groups were direct in their approach but would also concede space to allow movement as long as this would not impact upon their end goal – there was an understanding that space would be relinquished.
- Members of both groups would break away from the majority to allow groups to pass through – this was related to the on-going action of all others and reduced the overall impact upon movement.
- After adaptation “strong” personality types showed little regard for on-going ownership and would move in a way that reduced their effort when engaging with new content – this would be done without directly impacting an on-going experience, but did not concede space.
- Members of both groups would adopt less preferable positions to view content – combination of minimising effort in movement and not impacting on-going experiences.
- Members that lost touch with their group would follow their own agenda – there was little regard for the group experience which was reflected in the comments.
- Throughout the experience there are members who are aware of their immediate surroundings and work to adjust their position to support others experience.

Study 2:

- Participants approach the display based upon their preferences – physically taller members move to the rear while those at the front are aware of this and try to adjust their position.
- After adaptation there are several people trying to move and re-engage with new content – On-going interactions take precedent and there is little awareness or willingness to adjust.
- If there is an on-going interaction participants are usually willing to adopt a lesser position.

Study 3:

- There is negotiation between the groups towards the best approach – a late decision requires a quick response and the group moves through the interaction space.

- As there are multiple participants at the there is a need for leaning and adjustment by several people – instead of interrupting people at the display there are several small adjustments which can change the way content is viewed.
- Changes in one part of the display create space and allow for movement in other areas – participants will limit their movement if it will affect other, unless there is a clear goal.
- Participants will remove themselves form the group based on personal preference – when space became available the participant moved to an extreme end of the display.
- Once a good position was established there was no need to move – a participant stood centrally and engaged with all available content.

Across the three studies the outcome was generally the same. At the beginning of the interaction there was negotiation between the groups but this was solved amicably to utilise all of the space and allow quick access to the display. After the adaptation there were several types of response based on the types of on-going interactions, these included;

4) Deep engagement with content – High Focus, Low Awareness - Very unlikely to move.
5) Engaged but removed from the display – Mixture of Focus and Awareness – Observant
6) Not engaged – Aware of the situation – Response is relative to intention

These combined behaviours resulted in a clear group in the centre who did not move, with several people adjusting their positions or entirely moving relative to the display. What was of key interest was that relationship to personality type and intention. In types 1) and 2), a more passive response would see the person adjust relative to the current movement whilst maintaining their interaction. In case 3) this type of participant would be more observant of the actions and move after there was clear goal. Alternatively, more dominant types would simply adjust their position based on their immediate requirements, with secondary considerations for the effect. This would be seen in movement followed by awareness of the social situation.

What quickly stood out in this trial was that individual traits would have a significant impact on the observed behaviours. The resulting decisions of all participants would impact upon one another in a way that required constant re-evaluation form each member in a dynamic process, whether this was subtle adjustment between two or more individuals, or more out right behaviours in moving around the display. The key to the majority of behaviours was task evaluation and the relationship this had with adaptation in content. Based on the on-going levels of interaction and more overarching behaviours of each individual, there would be significant impact upon the group interaction.

Trial 2

This trial required two groups, one of five and the other two. Initially the first group would have the entire display and at a given time the second would be introduced requiring adaptation of the window layout. After a second break the width of the windows would adjust to allow members of the first to join the second. This was intended to investigate ownership of physical space and cross-group interaction.

This investigated; Ownership of physical space relative to display layout and group interaction.

What was seen;

Study 1:

- During adaptation there was general adjustment to maintain the interaction with the window – several members did not move as there was no need.
- By not moving there was no awareness of content adaptation behind their position – the introduction of a new group to this location caused them to move as they were blocking a clear interaction with the content.
- Changes to an on-going window i.e. shrinking, caused the group to bunch – there was the assumption the window was about to be removed.

Study 2:

- At adaptation the initial movement of participants was enough to allow their continued engagement – the remainder of the group had to then form rows behind.
- When realising there was additional content participants would select a location to allow maximum uptake.

Study 3:

- Immediately upon starting a participant steps forward to claim a key viewing location – this was in relation to the previous study and noted they did not like to have their view occluded.
- This starting location encouraged an extremely wide viewing circle – at adaptation there was no need to adjust with the change.
- The expected behaviours of participants was not required given the physical formation of the group – short participants did not need to move to the front of the group.

This trial saw two distinct patterns of behaviour which could be related to the initial mode of engagement. As only one group was interacting initially the approach of the second was highlighted by the adaptation – awareness of the changes in layout informed of the approach. During the adaptation there was general movement with the window as the ideal viewing position was central – a lack of understanding about the magnitude of the movement also encouraged this adjustment, however, once the adaptation had finished the adjustment was carried out to a minimum requirement for those closest to the display. The remainder of the group were then required to move behind these people but did not move past the group, but instead formed rows.

Participants to the left of the display were obliged to move once they became aware of the approaching group, which was not clear if they were unaware of the new window. This indicates that the space was not available for use as it restricted access to the second group’s content. As this window adapted there were mixed responses. The majority of participants did not move as they were able to view both windows from their current position, however, the secondary effect was that the shrinking of the first window signified its removal. This resulted in crowding to engage with the content before it was lost.

This trial saw several types of interaction behaviour;

1) High engagement with content – Focus is lost during adaptation – Moves with the window
2) Engaged with content – Awareness is limited based on starting position – No requirement to move
3) Engaged with content – High Focus – Starting position allows for selection of contents
4) Loss of engagement – Poor presentation resulted in a loss of interest – there was little motivation to move and re-engage

This trial posed different criteria as the Focal point of the interaction moved. Due to this, the effects of personality type were less pronounced as movement was more structured and there was a tendency for groups to move wholly, and so individual behaviours were not singled out. However, points of interest included;

- A dominant member approaching the display and claiming a location for interaction, this inadvertently resulted in a key viewing location throughout and no need to move.
- A passive member not adjusting with the group and not noticing a new group approaching – as they became aware they moved out of the interaction area and returned to their group.
- The effects of initial group formation limiting the need for adjustment during adaptation.
- Minimal movement to engage with new content – the preference was to re-orientate.

In this trial the effects of position were of significance to the unfolding of events and nature of individual interactions. Adaptation in the most part resulted in movement of users to allow a secondary window, however, a wide formation removed the need for this entirely and there was little perceivable effect. Further to this, the starting position had a key impact upon awareness of adaptation and required direct response when social interaction took place.

While personality type had less impact during this study there were still indications of the effects. More passive members would approach the interaction more cautiously and prefer to stand back during interactions, while dominance was seen in how movement and positioning came about. What was clear, was that the addition of a new window would result in a change in perceived ownership of the space. As a new group arrived the useable space for the current group would be reduced in the short term. However, as this new content was available to both groups the available space around the display was eventually used to maximise the potential to engage with content. The exception being when the initial formation provided access to all material from the beginning.

Trial 3

This trial was made up of three separate groups, two groups of three and a single person. The display initially had two windows which would compress and translate to the right side to allow a third window. After a period of time these would translate right, with the Red window shrinking to create enough space for an additional Red window on the opposite side of the display. This would test awareness across the entire display as well as the group's interactions between adjusting windows.

This investigated; Ownership of windows and the relationship to physical space as well as awareness across the display.

What was seen;

Study 1:

- During approach group would concede space to allow effective navigation of the area and quick access to the content – the first group to the display adopted a wide viewing angle causing the second group to form around them to access their content.
- Single participant takes up a removed viewing position to view all content – with multiple windows there was assessment of titles to find interesting content.
- Adaptation caused movement of the groups sideways and towards the display – the introduction of a new window resulted in the lateral movement.
- Adaptation would cause movement and also a break in Focus – participants would all adjust during these times to avoid interfering with and interaction.
- As density of people increased groups would move to available space to continue reading – this was more comfortable and allowed better viewing.

Study 2:

- Conscious of many people around – would read title and then decide where to interact
- Adaptation was the result of change – If Focus was high there was less Awareness and vice-versa
- After completion of articles those in the middle would engage with the nearest content – did not want to have to move around the display
- Some found the movement between Red windows interesting – made the experience about exploration, others did not like this
- The groups is standing further back form the display – this could be in response to the adaptation or as people are adjusting to reading the content.
- There is little thought about what others are doing or why – decisions are made based on what is happening in the immediate area.

Study 3:

- Groups in front of the display negotiate for access – based on the starting position one member waits for this to happen.
- Awareness of sight blocking causes adjustment of the groups.
- Adaptation causes movement sideways which affects those standing behind – this requires awareness of issues and adjustment for line of sight.
- A participant want to move across the display, there is adjustment to allow this – the majority of the group would be affected, instead they return and adjust their own position.

This trial had a distinct pattern of behaviour which may be explained by the density of groups, unlike the previous trial where compromise could be found between groups. The clear translation of the content windows resulted in very clear movement from participants as it was understood that a new group would require the space.

As there were multiple adaptations groups were continually required to adjust and the experience of most was affected. This is hard to clarify as there were issues relating to presentation which were significant, but the act of adjusting did not seem to overly both most. Again, as the point of focus was moving there were less pronounced effects due to personality type, apart from those who took up positions behind the group. This removed position allowed much wider freedom to select content and viewing position and did not require constant movement relating to adaptation.

The interaction types in this trial were limited, perhaps based on the requirements introduced by movement;

1) Engaged – High Focus – Would move with their content, understanding that additional groups were using the display
2) Engaged – Low focus – Generally moving with the group but reading content that appealed, switching between sources
3) Removed – Happy to read content but trying to avoid the effects of grouping and adaptation

The significant personality effects were related to type 3) interactions, where a preference for a removed viewing position and low density saw several members stand back form the display. The high density again reduced any impact of dominant members other than during initial approach and interaction, however, the bulk group movement simply required these people to move along with the group.

Trial 4

The final trial had only a single group. At two separate points additional windows would appear on either side of the main windows. These would be coloured for separate group (who were not present) and the windows would contain no content. The group was asked to consider their behaviours as if additional groups would approach and interact with these windows.

This investigated; The groups response to multiple intrusions on the interaction, as well as the relative formation to a compressed window.

What was seen;

Study 1:

- The main group approaches the display while two members take very wide viewing positions – These two have noted they do not like to be in the centre of the group.
- The first adaptation causes the extreme positions to adjust towards the centre but there is little response from any other members – the centre of the group have shifted their orientation with the window movement and have little awareness of the adjustment.
- The second adaptation causes adjustment form the extreme positions towards the centre, however there is no room for movement – the extreme positions move to the rear of the group causing slight adjustment form those in front to allow a view.
- Those in the middle wanted to adjust for best group experience, but there was no space to allow this – whole group felt compressed.

Study 2:

- Taller members move forwards quickly based on starting position – there is adjustment as smaller members move in front of them.
- After adaptation the group forms a wide semi-circle to allow line of sight.
- Second adaptation has limited effect on some members – others move to the rear but are unable to see past taller members.
- There is resistance to moving further around the group and the person struggles to view.

Study 3:

- Front participant does not want to be in the centre of the group – waits for the group to form and then joins the rear.
- Central position becomes blocked – instead of moving the participant leans around the obstruction, they are able to stay in the middle of the group without moving.
- Removed position allows for slight adjustment to maintain viewing.
- Adjustment at the front requires the participants to check and adjust to prevent view blocking – knock on effect through the middle of the group.
- Second adaptation causes the left side to move towards the middle – lack of space results in these members moving to the rear of the group.
- The whole group feel compressed during the experience.

This trial yielded some very interesting relationships within the group response. It was universally felt that multiple groups approaching an on-going interaction was a negative impact upon the experience. Comments suggested that these groups were of approximately the same size as the group of participants, which was interesting when considering the size of windows, with the central window being clearly bigger than both others. This idea of "compression" of the group initially resulted in adjustment of external members which had a small propagation effect, but this did not affect many members. However, the approach from the second side was significant. As the middle of the group had already adjusted once, this left little space for the external members to move inwards, resulting in their moving behind the group.

Of the participants that started at the rear of the group there was almost no need to adjust position throughout. The removed starting position required only minimal change to large adaptations without affecting viewing. As noted this was a product of personal preference and was seen consistently from some members. In this trial this type of behaviour was more consistent with type than actual personality traits;

1) Removed observer – preference to remain outside of the group – comfortable movement to allow interaction.
2) Central position – awareness of adjustment through the group – movement where possible to allow better access for more members – happy to engage and disengage with content as required.
3) Extreme position – aware of external groups – attempts to adjust slightly without affecting the group.

As this was a large group interaction the effects of type were diminished, however, the impact due to starting position and personal preference were significantly more evident. Without knowledge of the adaptation several members were forced to adjust their position to support the group interaction, as was noted when several participants wanted to "protect the group" and try to maintain the space held. All participants noted that during this experience they had actually felt like they belonged to a group and they were considering how others might respond.

What was more interesting to consider, was how individuals would adjust their positions based on external factors, whilst also considering the on-going interaction of the group. There was an understanding that their location was being impacted upon and while adjustment was required it should not affect the entire group.

** Break down of the thought process and definitions which must be established leading to conclusion of the study

- Analysis looks to consider how an individual behaves around the display as this then influences how groups will interact between one another.
- Define a group
- Groups that arrive together
    - This can be groups / individuals who want a separate experience
    - Groups that form around content – If the content moves then so does the group
    - Those who are engaging with multiple windows from a central position – They do not have a clear allegiance with one group or window, if there are adaptation it is hard to know how they will respond – This may relate to their personal traits or the current use of the space
- Defining an individual's behaviour:
- Position and Orientation
    - A decision must be made as to where to stand to engage with the content
    - This is a factor of approach, content and others in the space
    - They can be influenced by changes in the layout and behaviour of others
- Awareness and Focus
    - Awareness is generally applied to confirming interactions, this could be at the beginning of interaction or during changes
    - Awareness and Focus appear exclusive – As Focus goes up, Awareness goes down. This could include engaging with content or moving around the space.
    - Awareness can be related to the immediate area or to the display and changes in the group
- Factors that influence the individual:
- Personal traits / stereotypes
    - There tends to be an overarching approach to interaction, however, subtle changes in environment can influence immediate behaviours
    - There are further sub sets of behaviours that can be observed – action / reaction
- Local factors that influence decisions
    - Personal space
    - Line of sight
    - Awareness of obstruction / new members joining
    - Minimising movement – Awareness of content
- Group behaviours

    - Approaching groups – Considering the use of space / impact upon the group
    - Movement of the group – predicting interactions between groups
    - Relationship to an on-going interaction and the starting group
    - Internal group decision making – Moving to achieve a goal
- Display adaptations
    - Translation – Is there a need to move to maintain the interaction
    - Scaling – What is happening to the content – Nearer / Further to interaction
    - Presentation – What is the requirement for interaction
- Quality of interaction
    - How is the individual aligned to the display
    - How many people are using the window
    - What is the distance and presentation
    - Are there additional groups nearby
- Individuals have a continuous series of interactions that defines their experience – The actions that are observed are the combination of their behaviours, changes in the display and what the group is doing as a whole.
- Framework for considering each individual
    - Stereotype – Likely behaviour sets
    - Starting position / Awareness – Will influence approach relative to;
        - Content layout
        - Group movement
        - External group factors

Summary

User Study Behaviours Summary

- Factors of the Display – Position, Size, Density, Presentation, Supporting windows, Ownership
- Position and Orientation – These could be observed and related to the on-going behaviours
- Awareness and Focus – Had to be described by the participants – related to behaviours
- Stereotypes – What these were, how they related to behaviour

Study 2

What was seen:

Trial 1

- When two groups were approaching from opposite side of the display, one group would stop to allow the other to pass in front of the display. The group who were moving sped up to pass by quickly.
- Without a clear path to interact it was easier to wait and make a decision – Two separate participants – One waiting to move across the display, the other wanting to join the back – “When waiting to join the back, the initial line-up was easier to

join as there was less movement – it was clear where people were and what they were doing”

- There is awareness within the group – As a new member arrives there is a glance and adjustment from somebody at the rear – “Awareness for others approaching and wanted to make more space for others to have a good viewing position. There is not always space for everybody to have a good view”
- A person from the right side pushed towards the middle of the other group to be able to see the content – This meant they did not have to walk around the display – A second member of the same group took up a position behind them to view – This was worse than moving but did not require they went around the rea of the group – “Moving while all members were stationary was easier as there was clear space between people”.
- As one group finishes their interaction on one side of the display they move across to the other side, this opens up space for both groups to readjust for better viewing positions.
- One members remains in the centre of the display and read the content that is nearest

Trial 2

- During translation, several members moved in the direction of adaptation to maintain their viewing relationship with the window i.e. perpendicular. – “Did not want to disturb others who were already interacting, instead moved behind them”
- One member remained behind during adaptation causing the second group to have to adjust their starting viewing position - This person was not aware of the group of window. When they were noticed the person felt obliged to move behind their original group – “There was not enough space and so the group was forced to form two rows to read content”.
- Person at the right hand end of the display did not notice a new window at the left hand end until they had finished reading he content – They were not used to the adaptations and changes of the display – Did not want to engage with the content.
- When the window contracted the group moved in for a better view – There was an assumption that the content might be about to disappear – Wanted the best view possible to continue reading.

Trial 3

- One group had to move directly across the display and then took up a wide viewing formation – This resulted in the second group having to adjust their formation relative to the remaining space.
- By remaining back from the display it was possible to view multiple windows and the content during and after adaptations – While adaptation did cause the groups to move with the content, it was still possible to read the windows from the original location. The inclusion of additional windows required the groups to move.
- Once the content was finished there were several examples of reading the next nearest window – “Once the content had been read there was little intention of moving – Too many people to move easily, there was a second window nearby, the other windows would require a large amount of movement”.

- When new content windows appeared there may be a brief assessment of the title before carrying on with the article – This was to assess the new content to see what it was and if it might be more interesting than the current piece – "When adaptation took place there were changes to the whole display. This caused users to look at what had caused the change. This could be anything that triggers interest – Flashes of colour, movement" – "Participant was not aware of the additional windows until they were forced away from their window as presentation dropped, then they noticed additional content"
- When moving between windows it was preferable to avoid disrupting on-going experiences.
- If density around a group increased the participants would often adjust their positions to create more space for the additional group, even if there was very little of the article left to read.
- Being the third group was fine as there was plenty of time to read other articles – When the content did appear it was possible to finish reading and then start on the new content as it was unlikely to disappear any time soon.
- The Red group experience was harder as they were required to move a lot, when they did move across the display there was little room to join in the experience on the other side.
- During adaptation one participant moved away from the display in order to better see the changes – This allowed a better understanding of what was going on.
- There was little awareness of window size between each group. Some felt that Red had less / equal space, although this was split over multiple parts of the display.
- As the window shrinks it feels like it is about to disappear, so there is a rush to finish reading the content – "You do not know how long you have left to finish reading" – Difficult interaction for people who do not read quickly.

Trial 4

- The group moves directly to the centre of the display – The female members stand off to the side to allow a wider field of view.
- As additional groups approach from the sides there is limited space to adjust position – The result is compression in the centre of the group and those on the sides are forced to move to the rear – "The group folded around the middle – People did not want to be hemmed in"
- "As people were making space it was felt that the people at the edges of the group should move to make more space – this was distracting as you were4 unsure if you were going to have to move as well" – "People in the middle felt they had to move less, but there was still a need to adjust to accommodate those on the edges that were moving."
- People at the display did not want to move as they were there first – "Would have moved for children as they should be able to see" – "Tall people should move to the back – depends on the type of person, are they self-aware on the effect they will have"
- People did not know where to stand as they were unsure how large the window would be or how big additional groups were.

Appendix C – Implementation

C1 Sensing Technologies

Technology Matrix

Based on non-invasive technologies i.e. Non-instrumented. Technologies not considered: GPS, Bluetooth, RFID, Mobile App.

Technology	Coverage	Fidelity	Data	Data Availability	Limitations	Ranking
Time of Flights Camera – TOF Cost - £250	Several meters from camera. Defined area is subject to each camera model.	Low resolution – 320 x 240 pixels Limited to Limb and Pose detection – Poor estimation of Orientation. 6FPS.	Depth image. Skeletal pose can be found through post processing – upwards of 16 D.o.F Generally used for focussed areas of interest.	Severe limitations in raw Orientation data. Post processing is required for skeleton tracking.	Depth artefacts at the edges of detection, poor representation of people and surfaces behind. Limited Orientation detection.	Application – 3 Ease of Use – 4 Usefulness – 6 Engagement – 6 Total = 19
Kinect Depth Camera Cost - £85	$8m^2$ floor area. Several examples of multiple camera solutions to increase coverage.	Good resolution – 640 x 480 – Offering good gesture recognition. 24 FPS with 0.13m accuracy	Body Position and Orientation relative to the camera position. Skeletal pose detection.	Post processing required for skeleton tracking – Well developed SDK's available. Several solutions with multiple applications and add-ons for additional data.	Depth artefacts at edge of detection. Multiple camera solutions can increase resolution and accuracy.	Application – 9 Ease of Use – 8 Usefulness – 9 Engagement – 9 Total = 35
WiFi Cost - £90	Range of 20m form	0.3m accuracy.	Real world position	Complex algorithm required	Spatial configuratio	Application – 3

	transmitter. System can include multiple sensors.	Can determine and track individuals (single person). Can offer some pose estimation.	data along with limited Orientation and pose estimation.	for body tracking and Orientation – Software available.	n affects accuracy. Detection of Pose and Orientation must be trained per person.	Ease of Use – 3 Usefulness – 6 Engagement – 3 Total = 15

Technology	Coverage	Fidelity	Data	Data Availability	Limitations	Ranking
Ultrasonic transducer Cost - £30	4 m range per sensor, requires multiple sensors for extended range.	0.5m – A single sensor cannot determine Orientation or Posture at this time.	Requires multiple sensors – Can offer Position and fundamental pose estimation.	Signal distortion requires extremely complex algorithms.	Can only track an individual – Complex algorithms are required for Orientation data. This requires training data.	Application – 6 Ease of Use – 4 Usefulness – 2 Engagement – 3 Total = 15
Monocular Camera Cost - £270	Conic view cone – Specific range to camera type – Around 30m in horizontal orientation.	Dependant on camera type – Usually very high accuracy. 0.05 m.	Range of data sets – Pose estimation Tracking requires extensive analysis.	2D image – Requires post processing Ethical issues associated with identifying individuals.	Requires computer vision algorithm to determine Orientation. Positioning of camera for maximum coverage causes occlusion.	Application – 6 Ease of Use – 3 Usefulness – 6 Engagement – 5 Total = 20

Multiple cameras Cost - £130 each	100m^2 maximum 25m^2 for highest quality	0.02 – 0.04 m with 4 or 5 people in the room. Occlusion issue will reduce the accuracy.	Position / Posture / Gesture Dependant on the algorithm employed.	Multiple 2D images requires – Post processing, Alignment, Amalgamation, Recognition.	Data streams require processing for position. Further processing required for Orientation / Gesture	Application – 7 Ease of Use – 6 Usefulness – 6 Engagement – 6 Total = 25
Single row laser scanner Cost - £200 each	360m^2 allowing for around 30 people. This would allow for around 4% occlusion error.	0.03m at 70m range at 10Hz.	X/Y coordinate of individual legs. This can be translated in to gait information.	Gives a field of view of range relative to the scanner. Analysis is required to find gait and hence Orientation.	Works on a single plane – Multiple cameras are required to allow for multiple people in the space.	Application – 7 Ease of Use – 5 Usefulness – 8 Engagement – 7 Total = 27

C2 Kinect Report

Kinect sensor report

What does Kinect SDK do?

The Kinect v2 camera and supporting SDK v2.0, are peripheral sensing devices specifically designed to track motion and gestural interactions of users with a computer system. The Kinect camera uses a range of sensing approaches to determine;

- Colour image (0.50 – 8 meters @ 1920 x 1080 pixels up to 30 fps)
- Infra-Red imagery (0.50 – 4.5 meters @ 640 x 480 pixels up to 15 fps)
- In-plane Depth measurements (0.50 – 4.5 meters up to 15 – 30 fps dependant on lighting)
- Skeleton tracking of 6 people with 25 points per person between 15 – 30 fps
- Audio positioning to determine direction of audio source
- Gesture recognition from learnt gestures as well as machine learning for gesture training
- Hand gestures for on-screen manipulation – Grasping, Panning

These features have been built directly in to the SDK and can be accessed as a range of demonstrations straight out of the box. Alternatively, the user can construct extremely simple application to use this functionality and subscribe to features that are required with minimal work.

How is it constructed?

The Kinect SDK is high level Application Programming Interface (API) which is principally designed to abstract the complex data handling from the sensor in order to provide a simple, yet rich interface to the real time data produced by the sensor. The design approach taken provides a modular environment for implementation of various features as they are needed.

The code design approach allows for multiple listeners for separate data sources (listed above) from a single Frame Handler, each of which can support intensive processing operations asynchronously. However, the design of the Frame Handler maintains synchronisation between key frames from each data source independently. This minimises errors when using multiple data streams within algorithms, yet limits the ability to programmatically access historic data. Instead this requires considered coding to construct monitor for changes of on-going variables.

This approach results in reduced computational overhead when data sources are carefully selected, however, poor identification can result in memory leaks and data acquisition being lost. Yet this enforces good coding practices and more robust code.

What supporting documentation is available?

The Kinect SDK v2.0 has been released with extensive documentation to support development in a range of language, including Java, C++ and C#. The documentation comes in the form of downloadable examples which allows access to the source code of the applications, as well as comments within the code itself to provide a rich set of information about functionality. These examples document a series of minimal code implementations of some of the most useful functionality. In the majority of cases these functions can be implemented with no more than 20 lines of code. This type of abstraction is extremely helpful for quick iterations of development, however, it does reduce some of the potential functionality which may be useful. This will become apparent after some initial development work.

Many of these examples can also be run directly as working examples within the SDK development environment. This is a standalone environment designed for debugging and testing of development code. This allows for various features of the device to be turned on/off during testing, as well as stepping through code whilst viewing the sensor output.

Outside of the official documentation, there is a wide spanning user community to offer support as well as developing separate third party libraries. Many of these developers have indicated interests in multiple camera arrays, as well as extending the capabilities of the system to track multiple individuals simultaneously, either with a single or multiple cameras.

A documentation of examples that have run in Kinect SDK.

Based on an initial trial with the SDK it has been possible to run multiple examples “straight out of the box”, further to this, introductory tutorials show that image and depth data can be acquired through the sensor in a matter of minutes when constructing code. These examples were able to implement skeleton tracking and head position within ten minutes in a bare bones implementation.

The limitations of the approach come when complex algorithms must be implemented, however, these do little to inhibit the implementation of the data capture which appears to be extremely straight forward. The most complex part of the procedure is initialising the API within an Integrated Development Environment (IDE) to support the minimal requirements of the sensor/software. Although, this step has been simplified to a number of clicks, it does reduce the control over the low level functionality of the sensor itself.

Potential uses of the device in this project.

The device and SDK work straight out of the box and are capable of fully tracking six individuals, including; skeleton, posture, gesture and head position. This allows for a range of interactions with the system, which includes, point and click as well as swipe interactions that can be recognised by the system. The gestural interactions are currently limited to two of the six tracked persons which would allow for interaction with a display, however, this is restricted by the effectiveness of the sensor to accurately detect gestures outside of the plane of the sensor.

With this in mind, it would be highly possible to track multiple users (up to six) and allow two of these to interact directly with the display. The limitations in this are;

- The number of people that can be simultaneously tracked. This appears to be locked at six, however, all of these individuals will have full 25 point skeleton tracking. While this gives greater fidelity of interaction it limits the effectiveness of understanding the formation behaviours of those not in the initial six persons detected.
- The need for "in-plane" gesture detection form the sensor will limit the positioning that can be used. The requirement for gesture tracking would result in a low central position, while maximisation of capture area would suggest an elevated position.

Is Kinect SDK useful?

The device can offer skeleton tracking at large ranges (8m) for up to six people per device. This would constitute a large group interacting with the display, however, this limitation prevents multiple large groups being tracked by a single sensor. Additionally the need for in-plane gesture tracking limits the positioning of the device in order to observe multiple people. This could prove interesting if a smaller scale is selected to consider how, up to six, people may use an adaptive display, however, a multiple camera system or sensor fusion option would be required to track multiple formations in relation to a large display, as is the current intention of the research.

As a sensitising exercise the limitations on number of users does reduce the effectiveness, however, the inclusion of gesture tracking allows for a more explorative approach to interaction and formation behaviour. This could highlight further considerations for a larger scale investigation. Current limitations will only allow a single sensor and SDK pair running on a single computer, however, this appears to be something that has been restricted in the SDK software. This indicates that multiple sensors and SDK's on the same machine could be a possibility in the future. A cursory investigation has identified several hack solutions to this problem, yet, for the time being this is outside of the scope of the project.

Can this be done?

The initial indication form the supporting documentation is that multiple sensors can be achieved if multiple PC's are used. This introduces a complexity to the problem in terms of data management and amalgamation, as well as implementation of the SDK functionality on an amalgamated data stream. Yet, there are indication from documentation that multiple sensors can be supported on a single machine within the SDK environment.

The use of the sensor as it stands could be implemented with minimal effort and would provide several interesting research areas within the overall context of the proposal. As the technology becomes available to expand the sensing area, this understanding could prove invaluable to address the interaction of those around as well as adjacent to the display.

Can I use Kinect SDK?

Implementation of simple sensor function and data handling should be extremely achievable given the level of abstraction within the SDK. While some of the more complex function are written directly in C++, which adds a large level of complexity to the problem space, the majority is available in C# which will prove quick to implement. The use of C# would also allow for quick tie in's with Unity 3D modelling software which can be used to directly manage rendering and animation relative to the user's gesture and body posture.

The remainder of the development would focus on the addition of multiple sensors and the construction of gestural machine learning approaches. These would not be implemented directly by myself, but instead would rely on the publishers and third party applications, both of which are heavily discussed in forums and supported in current development. The implementation of these features should be no more difficult than the use of the SDK itself and there are examples of current implementations existing in the wild.

References

The majority of the SDK development reference is held within the "SDK Browser" which is locked to Windows development machines.

C3 Design

Data Flow

System data flow is based entirely on the position and orientation of users within the interaction space in front of the display. The interaction space is defined as the area that users can be captured by the Kinect cameras and a skeleton acquired from which an accurate position and orientation can be established.

As there are two cameras, data capture must be establish from each course independently before being re-combined and entered in to the main loop of the software. As a simplification, the power of the Kinect API is used to abstract the maximum amount of data from each frame before it is submitted to the main loop.

Client

As there are multiple cameras used, the data capture is run as a client in a client-server setup. Each data capture setup is run as an independent client and networked to the Server machine which runs the main system loop for data analysis. The client setup is described below (Fig. 1).

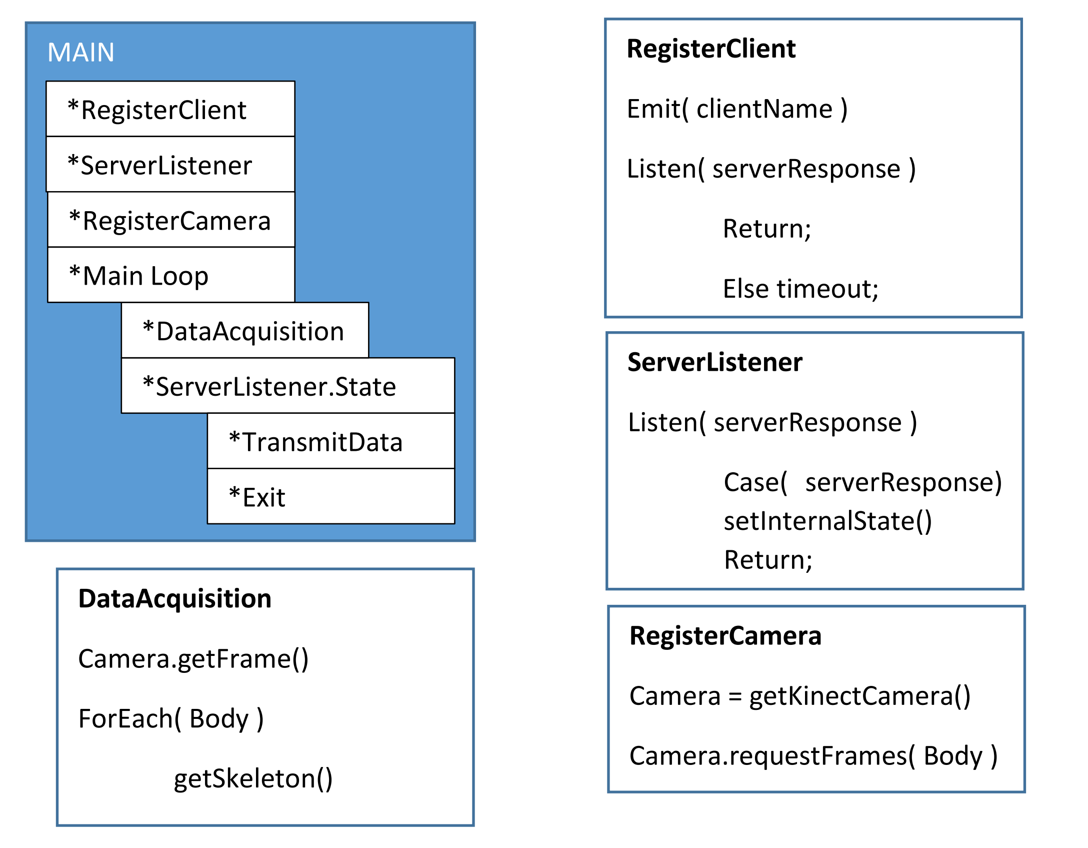


Fig. 1: Client system diagram for Kinect camera data capture

Once the client is registered with the server data will continue to be captured, simplified to skeleton points and transmitted based on pull requests from the server once input data has been updated on the server. Using pull requests from the server ensures the client does not push fresh data to the server before the server has finished executing its main loop which would result in a runtime error.

As a result, if the server has not requested new data before the new Kinect frame is captured the frame will be discarded and the client will execute its main loop again. This approach ensure the data is as fresh as possible for transmission to the server. Conversely, the Kinect API can discard a frame if there is not sufficient data within the frame to construct the skeleton data for each user. In this case the client will restart the main loop and re-transmit fresh data unless the server sends an exit message. This asynchronisity between client and server can lead to mismatch between multiple clients responding to the same pull request from the server. As such the server must account for discrepancies between the raw data streams form clients.

Server

As the server is responsible for all tracked users within the interaction space, each user tracked independently by both clients must be resolved to a single data source and updated with the most accurate data available. As a client is able to drop frames, resulting in a timing issue between data sources, the server must account for both fresh data and dropped frames when updating each users data as well as movement of users between subsequent frames.

To maximise synchronisation between the clients the server will emit a pull request after the execution of the Main Loop. This will request a fresh frame from each client and wait until both have submitted fresh data. At this point both data sources are resolved against one another to establish duplication of tracked users and which represents the most complete data per user. Once this is established the data can be passed to the main loop. This process is shown below (Fig. 2).

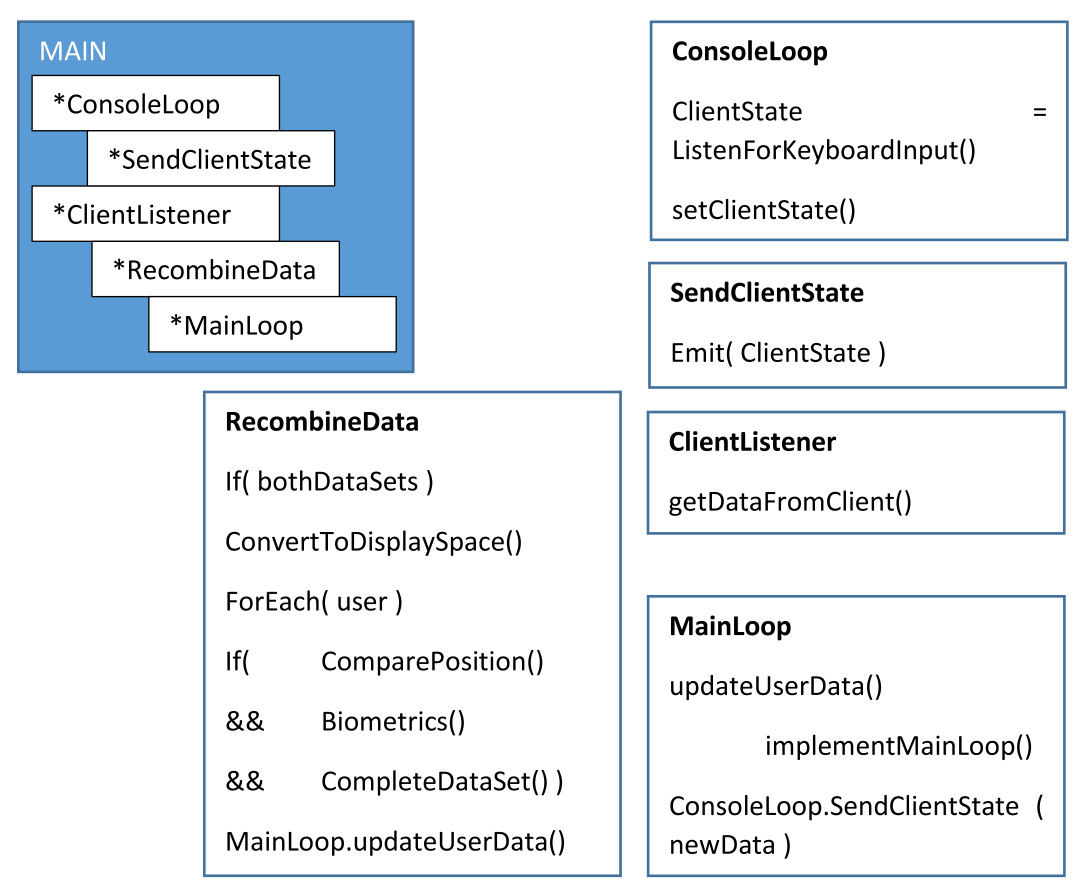


Fig. 2: Server system diagram for data handling

The console loop works to manage the lifecycle of the Server-Client process through users inputs to the console and by transmitting the pull requests from the main loop. This is the communication process between data sources and analysis. This approach aims to synchronise the data sources, but does not manage the returned data from these sources. Instead the client listener is a passive channel that will continually accept data from the clients to allow new data to be received if a client drops a frame or is out of synchronisation.

The synchronisation of the data sources is handled by the recombination of data, where issues of timing and accuracy are handled between the two clients. The first step is to compare the input data to existing data on the server to establish which user is being tracked. The old and new positions are compared to establish an approximation for which user the data belongs to. Biometric data form the skeleton, including height and body dimensions, is compared to establish a sanity check on the data sources to prevent mismatch between users in close proximity. If both checks are true then the two new sources are compared to establish the most complete data set (full skeleton) between the clients. This will ensure that users who are occluded can be tracked from multiple angles with the most accurate data used to update the main loop.

As timing between both clients has been established, there is no need to take the most up to date data set, instead accuracy and completeness of data are more important. Any issues that are introduced by using separate data sets (with timing error) can be managed by smoothing in the main loop and averaging of behaviours between frames.

By this process a single data set for each user can be found and submitted to update the main loop. Data from both clients cannot be used for this process as there are factors of camera position and the resolution of skeleton data done separately by each client.

Main Loop

The main loop runs in parallel with the Server loop and acts as the trigger for pull requests to the clients. This setup ensures the most accurate data is used when processing the camera frames to reduce errors between the independent data sources and any error introduced in translating the frames in to the display reference frame.

The main loop is responsible for assigning user data and managing the internal states of each user relative to their position and behaviours around the display and other users. This states are based on the HAMMER implementation and internal algorithms which describe the social behaviours seen in the field work. The implementation of these algorithms are directly linked to the development of system accuracy and are the core of the Ph.D. investigation. An example is shown below (Fig. 3).

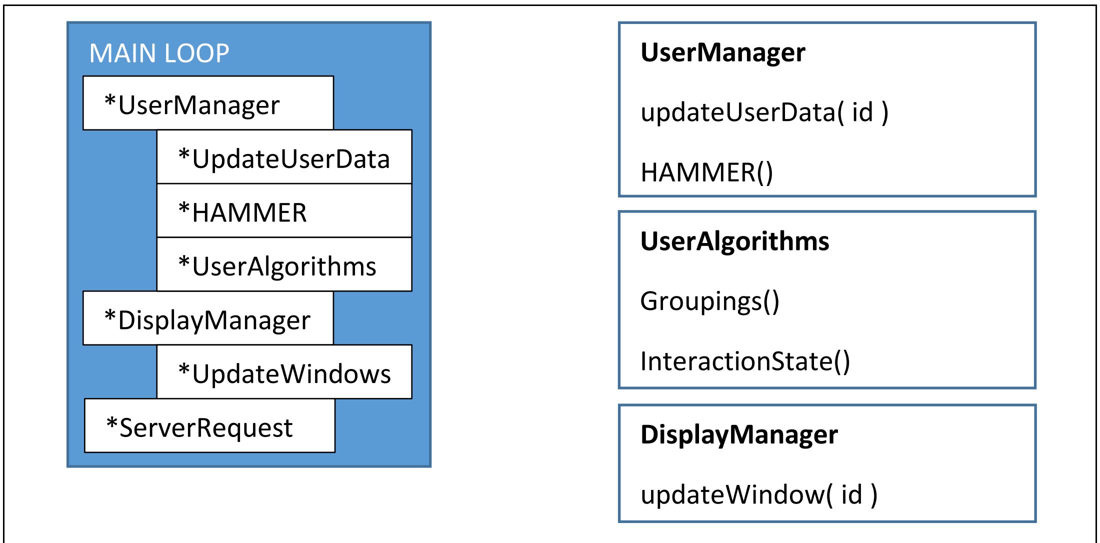


Fig. 3: The main loop diagram for data handling and calculation

The components of the main loop are managed in two parts. The first focusses on the user data and the internal states used to describe the behaviours of each user independently. These include the HAMMER implementation which identifies the movement behaviour based on the input data from the clients. User Algorithms abstract the user states and compare these to world state data, including relationships between users and windows to establish groups, as well as the interaction state of users to determine the content and adaptations shown.

The second component is the Display Manager, which is responsible for managing the content windows, their position, content shown and movements. These updates are related to the position of the user, their interaction state and HAMMER states. Each of these factors must be considered to determine the correct configuration of the display window. A further consideration of the display manager is the interactions between windows during movement or adaptation, such that windows do not interact with one another and maintain a given separation to support user experience.

The algorithms involved in both of these elements are derived from the observations and user studies carried out and are continually adjusted to better represent the on-going behaviours. As these approaches use the multi-threaded approach described by the HAMMER framework, multiple parallel algorithms describing the same behaviours can be implemented, with the most accurate model being selected. This approach supports design and testing of iterative algorithms based on the observations from field work and user studies with clear validation based on previous approaches and models.

User Manager

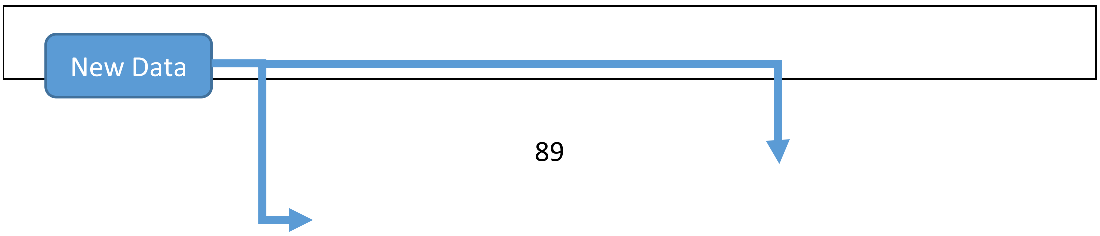
The User Manager class is a container for all of the individual user objects, each of which represents a single user that is actively tracked in the interaction space. The class provides loops to check user position and ID when updating new data from the server and separately manages the HAMMER and User Algorithms for users.

HAMMER

The HAMMER framework is native C++ API designed to support multithreaded parallel interpolative modelling of action-state pairs based on real time data. This approach allows for user defined algorithms to be modelled and compared to the next data point to establish the accuracy of each model and determine the most accurate real-time representation of the described behaviour. As the models interpolate the data the HAMMER implementation can be considered a classifier or behaviours, but cannot predict or make decisions about behaviour.

The framework relies on a wide range of simple models to provide a robust classification of the possible actions taking place. These models are representations of possible actions, where multiple actions may be represented in the data simultaneously. The ideal state will be that a single model possess a higher confidence than the others to accurately classify the on-going behaviour.

The HAMMER implementation is run within each User object independently of other agents. The new data point is compared to the previous run to determine the accuracy of the interpolation of the previous pass. Once this is done the new data is then run through the algorithms again to interpolate the next potential positions for the next data point. The most accurate model is then assigned to the internal state of the agent to provide richer knowledge about the interaction. A model of these state models can be seen below (Fig. 4).



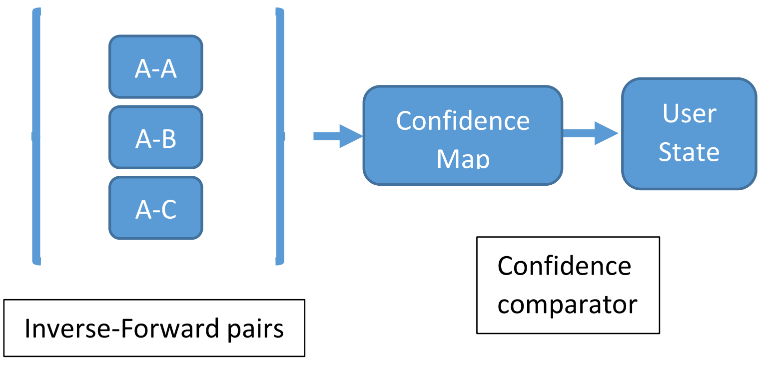


Fig. 4: HAMMER implementation to determine single user states

The HAMMER framework is responsible for the management of this process only and has no input to the user defined models or the confidence values established. All of these factors are described by user defined algorithms which are held within the Inverse-Forwards pairs and the confidence map. The framework is an API that is designed to streamline the process and management of these pairs.

As described above, the data point is passed to the model pairs to predict the next position of the user. This prediction is compared to the next data point when it comes in to the model to establish the most accurate prediction, where accuracy is determined by the preferred outcome of the classification models. In this scenario accuracy is defined by the prediction of the position of the user in the next data point. Each of these models can be as simple or complicated as defined by the system, however, multiple models can be run simultaneously, allowing testing of complex algorithms as well as simple classification of user behaviours.

The simplest form of algorithm identifies the position and direction of travel of the user, either moving towards or away from the display. However, more complicated combinations of information can provide information about the users interaction state. This includes the movement of the user through the interaction or observation spaces and their movement relative to content windows. Extrapolating the velocity and orientation of a user in relation to content windows can be used to identify the users intended target window as well as establishing the assumed group the user is interacting with. All of these factors can be defined by algorithm with enough thought and tested through the HAMMER implementation.

User Algorithms

While the HAMMER implementation can provide information about each users current behaviours and interactions with the system, translating these states in to meaningful data to inform the layout of the display requires the user information to be compared for all users to assess trends in behaviours. This indicates factors of groupings and on-going behaviours of interaction with content windows and other groups.

While the HAMMER framework can provide information about each user separately, the manner of interaction between users gives greater understanding about the overall use of the interaction space and engagement with the content. It is only through this approach that informed assumptions and predictive models of behaviour can be established to drive adaptation relative to these types of behaviours. These algorithms are a meta-analysis of user behaviours to be considered later.

Display Manager

By abstracting and simplifying user behaviours the requirements of the Display Manager are presentation of content and management of display real-estate. The complex behaviours of users are reduced to a position and interaction state to establish where the window should be positioned and what should be shown.

For all tracked users in the space these sets of data will be passed to the display manager to present the content window relative to user behaviours. As users are free to move throughout the space and interact with one another, interactions between windows must be handled to prevent the windows overlapping or interfering with an on-going interaction of another user. This requires the display manager to prioritise the windows to show and subsequently adjust the presentation of other windows to be shown. This configuration is based on the user data and User Algorithms to account for more complicated grouping behaviours. This class can be seen below (Fig. 5).

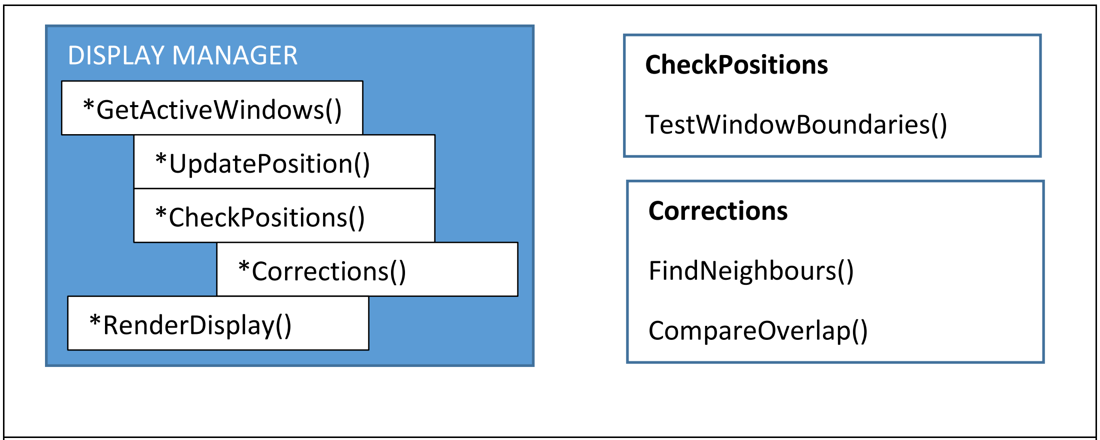


Fig. 5: The Display Manager class

Simplifying the layout of the display relative to complex user behaviours and interactions will be critical to the user experience to prevent confounding results between various users and their independent interactions with content. Understanding how user interact with the system will be critical to understanding and refining the models of interaction and classification of behaviours, so minimising the distractions to user behaviour will be important in establishing the accuracy of the system and understanding these behaviours.

The development of this model will be a key step in the user testing as it defines the parameters of the user experience and factors of interaction that cannot be established on static displays as are currently seen in the wild. Developing this understanding will go to inform the user behaviour models, delivery of content and interpolation of behaviour and interaction states between users, all of which is novel understanding of the problem space.

Code

Data Handler

```
using Microsoft.Kinect;
using Models;
```

```
using ServerData;
using System;
using System.Collections.Generic;
using System.Linq;
using System.Text;
using System.Threading.Tasks;
using System.Windows.Media.Media3D;

namespace _001___Server___Interaction_Manager
{
    class DataHandler
    {
        Models.ModelsHandler modelsHandler;

        private System.Timers.Timer dataTimeout;
        private int timeoutCounter = 0;
        private int timeoutInterval = 100; // ms - 10 DATA POINTS PER SECOND
        private bool transferStartedBool = false;

        public DataHandler(ModelsHandler modelsHandler)
        {
            this.modelsHandler = modelsHandler;

            this.dataTimeout = new System.Timers.Timer { Interval = timeoutInterval };
            this.dataTimeout.Elapsed += dataTimeout_Elapsed;
            this.dataTimeout.Start();
        }

        private void dataTimeout_Elapsed(object sender, System.Timers.ElapsedEventArgs
e)
        {
            this.timeoutCounter++;

            if (timeoutCounter >= 50 && transferStartedBool)
            {
                modelsHandler.PersonHandler.SetGroupDataToWindows();
                this.transferStartedBool = false;
            }
        }

        internal void SetRefernceFrameData(string clientID, double[] viewData)
        {
            this.modelsHandler.ViewsHandler.SetViewsData( clientID, viewData );
        }

        int counter = 0;
        Dictionary<JointType,   Point3D>   convPoints   =   new   Dictionary<JointType,
Point3D>();

        internal void PassData( string clientID, List<pPerson> personList )
        {
            this.transferStartedBool = true;
            this.timeoutCounter = 0;
            updateInt++;

            int   clientIndex   =   Int32.Parse(clientID.ElementAt(clientID.Length   -
1).ToString());

            foreach (pPerson person in personList)
            {
                Dictionary<JointType,          Point3D>          medianDict          =
PersonSmoothing(person.kinectID, person.bodyPointsDict);
                Dictionary<JointType,          Point3D>          convDict          =
ConvertPointsToRefernceFrame( medianDict, clientIndex);

                this.modelsHandler.PersonHandler.UpdatePersonData(
                    clientID,
                        person.kinectID,
                            person.bodyPointsDict,
                                person.csPoints,
                                    convDict,
                                        person.orientation );
            }

            //DEBUG - ADD PHANTOM PERSON DATA
            convPoints[JointType.SpineBase] = new Point3D(1, 0, 1);
            convPoints[JointType.ShoulderLeft] = new Point3D(0, 0, 0);
```

```
            convPoints[JointType.ShoulderRight] = new Point3D(0, 0, 0);
            convPoints[JointType.Head] = new Point3D(3, 2, 1);
            this.modelsHandler.PersonHandler.UpdatePersonData("CLIENT2",  00001,  new
Dictionary<JointType, Point3D>(),
                new List<ColorSpacePoint>(), convPoints, 0);
            // DEBUG

            //DEBUG - ADD PHANTOM PERSON DATA
            convPoints[JointType.SpineBase] = new Point3D(1.6, 0, 1);
            convPoints[JointType.ShoulderLeft] = new Point3D(0, 0, 0);
            convPoints[JointType.ShoulderRight] = new Point3D(0, 0, 0);
            convPoints[JointType.Head] = new Point3D(3, 2, 1);
            this.modelsHandler.PersonHandler.UpdatePersonData("CLIENT2",  00002,  new
Dictionary<JointType, Point3D>(),
                new List<ColorSpacePoint>(), convPoints, 0);
            // DEBUG

            //counter++;
            //if (counter > 100)
            //{
            //    // DEBUG - ADD PHANTOM PERSON DATA
            //    convPoints[JointType.SpineBase] = new Point3D(1.6, 0, 1);
            //    convPoints[JointType.ShoulderLeft] = new Point3D(0, 0, 0);
            //    convPoints[JointType.ShoulderRight] = new Point3D(0, 0, 0);
            //    convPoints[JointType.Head] = new Point3D(3, 2, 1);
            //    this.modelsHandler.PersonHandler.UpdatePersonData("CLIENT2", 00001,
new Dictionary<JointType, Point3D>(),
            //        new List<ColorSpacePoint>(), convPoints, 0);
            //    // DEBUG
            //}

            //if (counter > 200)
            //{
            //    // DEBUG - ADD PHANTOM PERSON DATA
            //    convPoints[JointType.SpineBase] = new Point3D(2.6, 0, 1);
            //    convPoints[JointType.ShoulderLeft] = new Point3D(0, 0, 0);
            //    convPoints[JointType.ShoulderRight] = new Point3D(0, 0, 0);
            //    convPoints[JointType.Head] = new Point3D(3, 2, 1);
            //    this.modelsHandler.PersonHandler.UpdatePersonData("CLIENT2", 00002,
new Dictionary<JointType, Point3D>(),
            //        new List<ColorSpacePoint>(), convPoints, 0);
            //    // DEBUG
            //}

            //if (counter > 300)
            //{
            //    // DEBUG - ADD PHANTOM PERSON DATA
            //    convPoints[JointType.SpineBase] = new Point3D(2.8, 0, 1);
            //    convPoints[JointType.ShoulderLeft] = new Point3D(0, 0, 0);
            //    convPoints[JointType.ShoulderRight] = new Point3D(0, 0, 0);
            //    convPoints[JointType.Head] = new Point3D(3, 2, 1);
            //    this.modelsHandler.PersonHandler.UpdatePersonData("CLIENT2", 00003,
new Dictionary<JointType, Point3D>(),
            //        new List<ColorSpacePoint>(), convPoints, 0);
            //    // DEBUG
            //}

            //if (counter > 400)
            //{
            //    // DEBUG - ADD PHANTOM PERSON DATA
            //    convPoints[JointType.SpineBase] = new Point3D(2.4, 0, 1);
            //    convPoints[JointType.ShoulderLeft] = new Point3D(0, 0, 0);
            //    convPoints[JointType.ShoulderRight] = new Point3D(0, 0, 0);
            //    convPoints[JointType.Head] = new Point3D(3, 2, 1);
            //    this.modelsHandler.PersonHandler.UpdatePersonData("CLIENT2", 00004,
new Dictionary<JointType, Point3D>(),
            //        new List<ColorSpacePoint>(), convPoints, 0);
            //    // DEBUG
            //}

            //if (counter > 500)
            //{
            //    // DEBUG - ADD PHANTOM PERSON DATA
            //    convPoints[JointType.SpineBase] = new Point3D(1, 0, 1);
            //    convPoints[JointType.ShoulderLeft] = new Point3D(0, 0, 0);
            //    convPoints[JointType.ShoulderRight] = new Point3D(0, 0, 0);
            //    convPoints[JointType.Head] = new Point3D(3, 2, 1);
```

```
            //    this.modelsHandler.PersonHandler.UpdatePersonData("CLIENT2", 00005, 
new Dictionary<JointType, Point3D>(),
            //        new List<ColorSpacePoint>(), convPoints, 0);
            //    // DEBUG
            //}

            //if (counter > 600)
            //{
            //    // DEBUG - ADD PHANTOM PERSON DATA
            //    convPoints[JointType.SpineBase] = new Point3D(0.2, 0, 1);
            //    convPoints[JointType.ShoulderLeft] = new Point3D(0, 0, 0);
            //    convPoints[JointType.ShoulderRight] = new Point3D(0, 0, 0);
            //    convPoints[JointType.Head] = new Point3D(3, 2, 1);
            //    this.modelsHandler.PersonHandler.UpdatePersonData("CLIENT2", 00006, 
new Dictionary<JointType, Point3D>(),
            //        new List<ColorSpacePoint>(), convPoints, 0);
            //    // DEBUG
            //}

            if (clientID == "CLIENT1")
                client1 = true;
            if (clientID == "CLIENT2")
                client2 = true;

            if (updateInt >= 10)
            {
                updateInt = 0;

                client1 = client2 = false;
                modelsHandler.PersonHandler.FlushInactiveUserIDs(
FlushInactiveSmoothingIDs() );
            }

            modelsHandler.PersonHandler.SetGroupDataToWindows();
        }

        bool client1 = false, client2 = false;
        int updateInt = 0;

    // ############################
        // DATA CONVERTER

        bool _BEHIND = true;
        double alpha = 51;
        double beta = 51;
        double displayOffset = 50;
        double cameraSeparation = 4590;
        double cameraDepth = 6250;
        double cameraOffset = 80;

        internal                    Dictionary<JointType,                    Point3D> 
ConvertPointsToRefernceFrame(Dictionary<JointType,     Point3D>     inputData,     int 
clientIndex)
        {
            if        (inputData[JointType.SpineBase].X        ==        0        && 
inputData[JointType.SpineBase].Y == 0)
                return inputData;

            Dictionary<JointType, Point3D> convertedData = new Dictionary<JointType, 
Point3D>();

            if (clientIndex == 3)
            {
                foreach (var point in inputData)
                {
                    Point3D convertedPoint = point.Value;

                    double x = (-1) * convertedPoint.X + ((cameraSeparation / 1000) / 
2);

                    double y = convertedPoint.Y;
                    double z = (cameraDepth / 1000) - convertedPoint.Z;

                    if (!_BEHIND)
                    {
                        x = convertedPoint.X + ((cameraSeparation / 1000) / 2);
                        z = convertedPoint.Z + (cameraOffset / 1000);
                    }
```

```
                    convertedPoint = new Point3D(x, y, z);

                    convertedData.Add(point.Key, convertedPoint);
                }
            }
            else
            {
                double cameraAngle = clientIndex == 1 ? alpha : beta;
                cameraAngle = cameraAngle / 180 * Math.PI;
                double vertAngle = 0;
                double pointAngle = 0;
                double compoundAngle = 0;
                double distance = 0;

                foreach (var point in inputData)
                {
                    Point3D newPoint = point.Value;
                    vertAngle = Math.Abs(Math.Atan(newPoint.Y / newPoint.Z));
                    pointAngle = Math.Atan(newPoint.X / newPoint.Z);
                    distance = Math.Sqrt((newPoint.Z * newPoint.Z) + (newPoint.Y *
newPoint.Y) + (newPoint.X * newPoint.X));

                    if (clientIndex == 1)
                    {
                        compoundAngle = (cameraAngle - pointAngle);
                    }
                    else if (clientIndex == 2)
                        compoundAngle = (cameraAngle + pointAngle);

                    double x = distance * Math.Cos(compoundAngle) *
Math.Cos(vertAngle);
                    double y = distance * Math.Sin(vertAngle);
                    double z = distance * Math.Sin(compoundAngle) *
Math.Cos(vertAngle);

                    //Console.WriteLine();
                    //Console.WriteLine("X: " + Math.Round(newPoint.X, 2) + " " +
Math.Round(x, 2));
                    //Console.WriteLine("Y: " + Math.Round(newPoint.Y, 2) + " " +
Math.Round(y, 2));
                    //Console.WriteLine("Z: " + Math.Round(newPoint.Z, 2) + " " +
Math.Round(z, 2));

                    if (clientIndex == 1)
                        x -= (displayOffset / 1000);
                    if (clientIndex == 2)
                        x = (cameraSeparation / 1000) - x;

                    newPoint = new Point3D(x, newPoint.Y, z);

                    convertedData.Add(point.Key, newPoint);
                }
            }

            //Point3D posL = convertedData[JointType.ShoulderLeft];
            //Point3D posR = convertedData[JointType.ShoulderRight];

            //Console.WriteLine( Math.Round(posL.X,2) + " " + Math.Round(posR.X,2) + "
" +Math.Round(posL.Z,2) + " " +Math.Round(posR.Z,2));

            //Console.WriteLine();
            //Console.WriteLine("********");

            //if( clientIndex == 1)
            //      Console.WriteLine( "CLIENT1 " + Math.Round( pos.X, 2) + " " +
Math.Round( pos.Z, 2));

            //if (clientIndex == 2)
            //       Console.WriteLine("CLIENT2 " + Math.Round(pos.X, 2) + " " +
Math.Round(pos.Z, 2));

            //Console.WriteLine("ANGLE " + string.Format("{0:0.00}", ( compoundAngle
/Math.PI * 180 ))
            //    + " " + string.Format("{0:0.00}", (pointAngle/Math.PI * 180 )));

            //Console.WriteLine("POS " + clientIndex
```

```
            //                     + " " + string.Format("{0:0.00}", pos.X)
            //                     + " " + string.Format("{0:0.00}", pos.Z));

            //Console.WriteLine(clientIndex         +         "         "         +
convertedData[JointType.SpineBase].X + " " + convertedData[JointType.SpineBase].Z);

            return convertedData;
        }

    // ############################
        // DATA SMOOTHING

        Dictionary<ulong,  userSmoothing>  userSmoothingDict  =  new  Dictionary<ulong,
userSmoothing>();

        internal List<ulong> FlushInactiveSmoothingIDs()
        {
            List<ulong> usersToBurn = (from user in userSmoothingDict
                                   where user.Value.Active == false
                                   select user.Key).ToList();

            foreach (var userKey in usersToBurn)
                userSmoothingDict.Remove( userKey );

            foreach (var user in userSmoothingDict)
                userSmoothingDict[user.Key].Active = false;

            return usersToBurn;
        }

        private   Dictionary<JointType,   Point3D>   PersonSmoothing(ulong   kinectID,
Dictionary<JointType, Point3D> bodyPointsDict)
        {
            if (!userSmoothingDict.ContainsKey(kinectID))
            {
                userSmoothingDict[ kinectID ] = userSmoothing.Create();
                userSmoothingDict[kinectID].AddNewFrame( bodyPointsDict );
            }
            else
                userSmoothingDict[kinectID].AddNewFrame(bodyPointsDict);

            return userSmoothingDict[kinectID].SmoothedData;
        }

        class userSmoothing
        {
            Dictionary<JointType, List<Point3D>> smoothingDict;
            Dictionary<JointType, Point3D> medianDict;
            static int smoothingInt = 7;
            int medianPos = (smoothingInt - 1) / 2;
            double stdDev;

            bool active;

            public static userSmoothing Create()
            {
                return new userSmoothing()
                {

                    smoothingDict = new Dictionary<JointType,List<Point3D>>(),
                    medianDict = new Dictionary<JointType,Point3D>(),

                    Active = true
                };
            }

            public void AddNewFrame(Dictionary<JointType, Point3D> bodyPointsDict)
            {
                Active = true;

            // VALIDATE THE NOISE IN NEW FRAME BEFORE ADDING

                // IF LENGTH OF POINT - POSITION > 2 * VARIANCE
                // IGNORE THE SET AND RETURN

                //double                          variance                           =
VariancePosition(GetPositionSpineList(smoothingDict));
```

```
            //Console.WriteLine(Math.Round(CalculatePointsLength(
            //                         GetPositionSpine(bodyPointsDict),
            //                         GetPositionSpine(medianDict)), 2)
            //                    + " " + Math.Round(variance, 2));

            foreach( var joint in bodyPointsDict )
            {
                if (!smoothingDict.ContainsKey(joint.Key))
                {
                    smoothingDict[joint.Key] = new List<Point3D>();
                    smoothingDict[joint.Key].Add(joint.Value);

                    medianDict[joint.Key] = new Point3D();
                }
                else
                {
                    if (smoothingDict[joint.Key].Count >= smoothingInt)
                    {
                        smoothingDict[joint.Key].RemoveAt(smoothingInt - 1);
                    }

                    smoothingDict[joint.Key].Insert(0, joint.Value);
                }
            }

            foreach (var joint in smoothingDict)
            {
                if (smoothingDict[joint.Key].Count >= smoothingInt)
                {
                    medianDict[joint.Key]                                    =
MedianFilterPoints(smoothingDict[joint.Key]);
                }
            }
        }

        private Point3D MedianFilterPoints(List<Point3D> pointList)
        {
            var sortedPositionsX = (from point in pointList
                                    orderby point.X ascending
                                    select point.X);

            var sortedPositionsY = (from point in pointList
                                    orderby point.Y ascending
                                    select point.Y);

            var sortedPositionsZ = (from point in pointList
                                    orderby point.Z ascending
                                    select point.Z);

            double x = sortedPositionsX.ElementAt(medianPos);
            double y = sortedPositionsY.ElementAt(medianPos);
            double z = sortedPositionsZ.ElementAt(medianPos);

            return new Point3D(x, y, z);
        }

        private double VariancePosition(List<Point3D> positionList)
        {
            double x = 0, y = 0, z = 0;
            int count = positionList.Count;

            foreach (var point in positionList)
            {
                x += point.X;
                y += point.Y;
                z += point.Z;
            }

            x = x / count;
            y = y / count;
            z = z / count;

            double varX = 0, varZ = 0;
            double dX = 0, dZ = 0;

            foreach (var point in positionList)
            {
```

```
                    dX = point.X - x;
                    dZ = point.Z - z;

                    varX += ( dX * dX );
                    varZ += ( dZ * dZ );
                }

                return (varX + varZ ) / count;
            }

            internal     List<Point3D>     GetPositionSpineList(Dictionary<JointType,
List<Point3D>> bodyPointsDict)
            {
                List<Point3D> positionList = new List<Point3D>();

                if (bodyPointsDict.ContainsKey(JointType.SpineBase))
                    positionList = bodyPointsDict[JointType.SpineBase];
                else if (bodyPointsDict.ContainsKey(JointType.SpineMid))
                    positionList = bodyPointsDict[JointType.SpineMid];
                else if (bodyPointsDict.ContainsKey(JointType.Head))
                    positionList = bodyPointsDict[JointType.Head];

                return positionList;
            }

            internal    Point3D    GetPositionSpine(Dictionary<JointType,     Point3D>
bodyPointsDict)
            {
                Point3D position = new Point3D();

                if (bodyPointsDict.ContainsKey(JointType.SpineBase))
                    position = bodyPointsDict[JointType.SpineBase];
                else if (bodyPointsDict.ContainsKey(JointType.SpineMid))
                    position = bodyPointsDict[JointType.SpineMid];
                else if (bodyPointsDict.ContainsKey(JointType.Head))
                    position = bodyPointsDict[JointType.Head];

                return position;
            }

            public double CalculatePointsLength(Point3D pt1, Point3D pt2)
            {
                double diffX = pt1.X - pt2.X;
                double diffY = pt1.Y - pt2.Y;
                double diffZ = pt1.Z - pt2.Z;

                return Math.Sqrt((diffX * diffX) + (diffZ * diffZ));
            }

            public Dictionary<JointType, Point3D> SmoothedData
            {
                get { return medianDict; }
            }

            public bool Active
            {
                get { return this.active; }
                set { this.active = value; }
            }

            public double variance
            {
                get { return this.stdDev; }
                set { this.stdDev = value; }
            }
        }
    }
}
```

MainWindow

```
using System;
using System.Collections.Generic;
using System.Linq;
using System.Runtime.InteropServices;
using System.Text;
using System.Threading;
using System.Threading.Tasks;
```

```
using System.Windows;
using System.Windows.Controls;
using System.Windows.Data;
using System.Windows.Documents;
using System.Windows.Input;
using System.Windows.Interop;
using System.Windows.Media;
using System.Windows.Media.Imaging;
using System.Windows.Navigation;
using System.Windows.Shapes;

namespace _001___Server___Interaction_Manager
{
    public partial class MainWindow : Window
    {
        static Models.ModelsHandler modelsHandler;
        static View viewController;

        static ConsoleHelper consoleHelper;
        static Server server;
        static DataHandler dataHandler;

        Timer drawTimer;

        [DllImport("USER32.DLL")]
        public static extern IntPtr FindWindow(String className, String windowName);

        [DllImport("USER32.DLL", SetLastError = true)]
        public static extern bool SetWindowPos(IntPtr hWnd, IntPtr hWndInsertAfter,
int left, int top, int width, int height, uint flags);


        public MainWindow()
        {
            modelsHandler = new Models.ModelsHandler();
            viewController = new View(this, modelsHandler);

            dataHandler = new DataHandler( modelsHandler );
            server = new Server( dataHandler );

            consoleHelper = new ConsoleHelper( this );
            consoleHelper.ConstructHelpList();

            Thread consoleThread = new Thread( ConsoleThread );
            consoleThread.SetApartmentState( ApartmentState.STA );
            consoleThread.Start();

            Loaded += MainWindow_Loaded;

            InitializeComponent();
        }

        void MainWindow_Loaded(object sender, RoutedEventArgs e)
        {
            viewController.SetAllCanvas(this.bodyPointsCanvas1,
this.bodyPointsCanvas2, this.mainCanvas, this.backgroundCanvas);
            StartDrawCallback();

            Window main = Application.Current.MainWindow;

            double windowWidth = System.Windows.SystemParameters.VirtualScreenWidth;
            double windowHeight = System.Windows.SystemParameters.VirtualScreenHeight;

            double offset = 7;

            main.WindowStyle = WindowStyle.None;
            main.ResizeMode = System.Windows.ResizeMode.NoResize;
            int mainWidth = (int)(( 2 * windowWidth ) + ( 2 * offset ));
            var mainHeight = windowHeight + offset;

            var TOP = new IntPtr(0);
            uint SHOWWINDOW = 0x0040, NOCOPYBITS = 0x0100, NOSENDCHANGING = 0x0400;
            var wih = new WindowInteropHelper(main);
            IntPtr hWnd = wih.Handle;
            SetWindowPos(hWnd, TOP, (int)(-offset), (int)(-offset), (int)mainWidth,
(int)mainHeight, NOCOPYBITS | NOSENDCHANGING | SHOWWINDOW);
        }
```

```
// CONSOLE THREAD

        static void ConsoleThread()
        {
            for (; ; )
            {
                Console.WriteLine("TYPE 'input' COMMAND OR - 'help'");
                consoleHelper.ConsoleInput(Console.ReadLine().ToString());
                Console.WriteLine();
            }
        }

// DRAWING CALLBACK

        public void StartDrawCallback()
        {
            Console.WriteLine("DRAW CALLBACK STARTED");
            TimerCallback viewControllerCallback = new TimerCallback(Draw);
            if ( drawTimer == null )
            {
                Console.WriteLine("TIMER NULL");
                Console.WriteLine();
                drawTimer = new Timer( viewControllerCallback, null, 0, 20 );
            }
            GC.KeepAlive( drawTimer );
        }

        static public void Draw(Object stateInfo)
        {
            Application.Current.Dispatcher.Invoke(
                  System.Windows.Threading.DispatcherPriority.Normal,
                  new Action(
                    delegate()
                    {
                        viewController.DrawAllPersonData();
                    }
                ));
        }

        public void SetUserName( string userName )
        {
            modelsHandler.PersonHandler.SetUserName(userName);
        }
    }

// CONSOLE HELPER

    public class ConsoleHelper
    {
        MainWindow main;

        static List<string> helpFunctions = new List<string>() { "draw", "transfer",
"end", "close", "exit", "*'USER NAME'" };
        public static Dictionary<string, int> helpList = new Dictionary<string, int>();
        public static Dictionary<string, string> helpDescriptions = new
Dictionary<string, string>();

        public ConsoleHelper(MainWindow main)
        {
            this.main = main;
        }

        public void ConstructHelpList()
        {
            int counter = 0;
            foreach (string function in helpFunctions)
            {
                helpList.Add(function, counter);
                counter++;

                if (!helpDescriptions.ContainsKey(function))
                    helpDescriptions.Add(function, function);
            }

            helpDescriptions["draw"] = "      --  start drawing callback";
            helpDescriptions["transfer"] = "  --  begin data transfer";
```

```
            //helpDescriptions["r"] = "  --  begin registration";
            //helpDescriptions["d"] = "  --  depth registration";
            helpDescriptions["*'USER NAME'"] = "        --  Set the User Name";
            helpDescriptions["end"] = "        --  end data transfer";
            helpDescriptions["close"] = "      --  closes ALL CLIENTS";
            helpDescriptions["exit"] = "       --  EXIT the application";
        }

        internal void ConsoleInput(string input)
        {
            string userName = null;
            if ( input.Length > 0 && input[0] == '*')
            {
                userName = input.Substring( 1 );
                input = input[0].ToString();
            }

            switch (input)
            {
                case ("draw"):
                    main.StartDrawCallback();
                    break;

                case ("help"):
                    Console.WriteLine();
                    Console.WriteLine("'input' COMMANDS:");
                    foreach (string function in ConsoleHelper.helpList.Keys)
                    {
                        Console.WriteLine(function                                  +
ConsoleHelper.helpDescriptions[function]);
                    }
                    break;

                case ("transfer"):
                case ("end"):
                case ("close"):
                    Server.SendCodeToClientList(input);
                    break;

                case("*"):
                    if (userName != null)
                    {
                        main.SetUserName( userName );
                        userName = null;
                    }
                    break;

                //case ("r"):
                //    System.Threading.Thread.Sleep(2000);
                //    Server.RequestRegistration();
                //    break;

                case ("exit"):
                    Server.SendCodeToClientList(input);
                    Environment.Exit(0);
                    break;
            }
        }
    }
}
```

Server

```
using ServerData;
using System;
using System.Collections.Generic;
using System.Linq;
using System.Net;
using System.Net.Sockets;
using System.Text;
using System.Threading;
using System.Threading.Tasks;
```

```
namespace _001___Server___Interaction_Manager
{
    class Server
    {
        static DataHandler dataHandler;

        static Socket listenerSocket;
        static List<ClientData> clientsList;

        private static Mutex updateUserDataMutex = new Mutex();

        public Server( DataHandler inDataHandler )
        {
            dataHandler = inDataHandler;

            Console.WriteLine("*** Starting Server on " + Packet.GetIPforAddress());

            listenerSocket = new Socket(AddressFamily.InterNetwork, SocketType.Stream,
ProtocolType.Tcp);
            clientsList = new List<ClientData>();

            IPEndPoint ip = new IPEndPoint( IPAddress.Parse( Packet.GetIPforAddress()
), 4242 );

            listenerSocket.Bind(ip);

            Thread listenThread = new Thread( ListenThread );
            listenThread.SetApartmentState( ApartmentState.STA );
            listenThread.Start();
        }

        static void ListenThread()
        {
            for (; ; )
            {
                Console.WriteLine("LISTENING");

                listenerSocket.Listen(0);

                clientsList.Add( new ClientData( listenerSocket.Accept() ) );
            }
        }

        public static void DataIN(object cSocket)
        {
            Socket clientSocket = (Socket)cSocket;

            byte[] buffer;
            int readBytes;

            for (; ; )
            {
                try
                {
                    buffer = new byte[clientSocket.SendBufferSize];

                    readBytes = clientSocket.Receive( buffer );

                    if ( readBytes > 0 )
                    {
                        if (!updateUserDataMutex.WaitOne(100))
                        {
                            Console.WriteLine("LOCK FAILED!!!!!");
                        }
                        else
                        {
                            DataManager(new Packet(buffer));
                            updateUserDataMutex.ReleaseMutex();
                        }
                    }
                }
                catch (SocketException ex)
                {
                    Console.WriteLine("A client disconnected");
                    SendCodeToClientList("exit");
                    throw (ex);
                }
```

```
            }
        }

        public static void DataManager( Packet packet )
        {
            switch ( packet.packetType )
            {
                case PacketType.RegisterClient:
                    Console.WriteLine( "REGISTERING " + packet.clientID );
                    dataHandler.SetRefernceFrameData(                packet.clientID,
packet.referenceFrameData );
                    Console.WriteLine();
                    break;

                case PacketType.Transfer:
                    if ( packet.personList.Count() > 0 )
                        dataHandler.PassData( packet.clientID, packet.personList );
                    //SendCodeToClientList("transfer");
                    break;

                case PacketType.InputCode:
                    break;
            }
        }

        public static void SendCodeToClientList( string inputCode )
        {
            Packet packet = new Packet( PacketType.InputCode, "server" );
            packet.clientCode = inputCode;

            foreach (ClientData c in clientsList)
            {
                c.clientSocket.Send( packet.ToBytes() );
            }
        }
    }

    class ClientData
    {
        public Socket clientSocket;
        public Thread clientThread;
        public string id;

        public ClientData()
        {
            id = Guid.NewGuid().ToString();
            clientThread = new Thread(Server.DataIN);
            clientThread.Start(clientSocket);
            SendRegistrationPacket();
        }

        public ClientData(Socket clientSocket)
        {
            this.clientSocket = clientSocket;
            id = Guid.NewGuid().ToString();
            clientThread = new Thread(Server.DataIN);
            clientThread.Start(clientSocket);
            SendRegistrationPacket();
        }

        public void SendRegistrationPacket()
        {
            Packet packet = new Packet( PacketType.RegisterClient, "server" );
            clientSocket.Send( packet.ToBytes() );
        }
    }
}
```

Views

```
using Microsoft.Kinect;
using Models;
using ServerData;
using System;
using System.Collections.Generic;
```

```
using System.Linq;
using System.Reflection;
using System.Text;
using System.Threading;
using System.Threading.Tasks;
using System.Windows;
using System.Windows.Controls;
using System.Windows.Media;
using System.Windows.Media.Media3D;
using System.Windows.Shapes;

namespace _001___Server___Interaction_Manager
{
    class View
    {
        MainWindow main;
        Models.ModelsHandler modelsHandler;

        Canvas bodyPointsCanvas1, bodyPointsCanvas2, mainCanvas, backgroundCanvas;
        double canv1Height, canv1Width;
        double canv2Height, canv2Width;
        double mainCanvHeight, mainCanvWidth;
        double backgroundCanvasWidth, backgroundCanvasHeight;

        double refFrameDepth, refFrameHeight, refFrameWidth;
        double cam1RefDepth, cam1RefHeight, cam1RefWidth = 0;
        double cam2RefDepth, cam2RefHeight, cam2RefWidth = 0;

        public View(MainWindow inMain, Models.ModelsHandler modelsHandler)
        {
            this.main = inMain;
            this.modelsHandler = modelsHandler;

            displayWidth = modelsHandler.ViewsHandler.DisplayWidth;
            displayOffset = modelsHandler.ViewsHandler.DisplayOffset;

            Thread modelListenerThread = new Thread( ModelListenerThread );
            modelListenerThread.SetApartmentState( ApartmentState.STA );
            modelListenerThread.Start();
        }

        void ModelListenerThread()
        {
            for (; ; )
            {
                if ( modelsHandler.ViewsSetBool )
                {
                    GetViewsFrameRefs();
                    modelsHandler.ViewsSetBool = false;
                }
                else
                {
                    if (modelsHandler.AllPersonsUpdatedBool)
                    {
                        dataDelay = 0;

                        GetAllPersonData();

                        modelsHandler.PersonHandler.TargetDict                       =
modelsHandler.ViewsHandler.GetTargetDict();

                        modelsHandler.AllPersonsUpdatedBool = false;
                    }
                }
            }
        }

        /// <summary>
        /// DRAWING FUNCTIONS
        /// </summary>

        Boolean USING_TRAJECTORY_MAPS = false;
        Boolean drawing = false;
        Boolean getDrawDataBool = false;
        List<ColorSpacePoint> client1Points = new List<ColorSpacePoint>();
        List<ColorSpacePoint> client2Points = new List<ColorSpacePoint>();
        List<ContentWindow> windowList = new List<ContentWindow>();
```

```
        Dictionary<int,  ContentWindow>  windowDictionary  =  new  Dictionary<int,
ContentWindow>();
        List<trajectoryStruct> trajectoryList = new List<trajectoryStruct>();
        Dictionary<int,  List<targetStruct>>  targetDict  =  new  Dictionary<int,
List<targetStruct>>();
        List<Point3D> personPositionsList = new List<Point3D>();

// ########################
        //GET PERSON DATA

        private void GetAllPersonData()
        {
            if (!drawing)
            {
                this.getDrawDataBool = true;

                FlushData();

                Dictionary<int,      ContentWindow>      windowDict      =      new
Dictionary<int,ContentWindow>( modelsHandler.ViewsHandler.WindowDictionary);
                Dictionary<double, Person> personData = new Dictionary<double,Person>(
modelsHandler.PersonHandler.PersonDict );

                foreach (ContentWindow window in windowDict.Values)
                {
                    if( window != null && window.Updated )
                        windowList.Add(window);
                }

                windowList  =  windowList.OrderByDescending(  wind  =>  wind.PositionZ
).ToList();

                if (USING_TRAJECTORY_MAPS)
                {
                    if (personData.Count > 0)
                    {
                        // TO DO - WRITE RETURN FOR TRAJECTORYLIST IN PERSON &&
MODELLING
                        //trajectoryList                                          =
personData[personData.Keys.Max()].GetPredictionModelsList();
                        personPositionsList     =     personData.Select(person     =>
person.Value.Position).ToList();
                    }

                    targetDict     =     new     Dictionary<int,List<targetStruct>>(
modelsHandler.PersonHandler.TargetDict );
                }

                //foreach (Person person in personData.Values)
                //{
                //    if (person.Updated)
                //    {
                //        foreach (ColorSpacePoint point in person.CSPointsList1)
                //        {
                //            client1Points.Add(point);
                //        }

                //        foreach (ColorSpacePoint point in person.CSPointsList2)
                //        {
                //            client2Points.Add(point);
                //        }
                //    }
                //}

                this.getDrawDataBool = false;
            }
        }

        int dataDelay = 0;
        public void DrawAllPersonData()
        {
            //DrawBackground();

        // RESET BY MODEL LISTENER - NEW DATA
            ++dataDelay;

            if (dataDelay >= 50)
```

```
    {
// NO INPUT DATA - TIMEOUT
    // FLUSH SYSTEM
        dataDelay = 0;
        FlushData();
        modelsHandler.PersonHandler.ResetPersonHandler();
    }

    if ( !getDrawDataBool )
    {
        drawing = true;

        DrawToMainCanvas(windowList);

        //DrawToCanvas1( client1Points );
        //DrawToCanvas2( client2Points );

        drawing = false;
    }
}

public void FlushData()
{
    this.client1Points.Clear();
    this.client2Points.Clear();
    this.windowList.Clear();
    this.colorRef.Clear();

    this.trajectoryList.Clear();
    this.personPositionsList.Clear();
}

// ########################

int position = 0;
bool forwards = true;

internal void DrawBackground()
{
    backgroundCanvas.Children.Clear();

    if (position > backgroundCanvasWidth)
        forwards = false;
    else if (position < 0)
        forwards = true;

    if (forwards)
        ++position;
    else
        --position;

    Ellipse ellipse = GetRedEllipse();

    ///SET POSITION AND ADD TO CANVAS
    Canvas.SetLeft(ellipse, position - (ellipse.Width / 2));
    Canvas.SetTop(ellipse, 200 - (ellipse.Height / 2));

    this.backgroundCanvas.Children.Add(ellipse);
}

// ########################

double displayWidth;
double displayOffset;

private void DrawToMainCanvas(List<ContentWindow> windowList)
{
    mainCanvas.Children.Clear();

    if (USING_TRAJECTORY_MAPS)
        DrawTrajectoryMaps( trajectoryList );

    foreach (ContentWindow window in windowList)
    {
// WINDOW ANIMATION

        window.CalculateDrawPosition();
```

```
        // WINDOW STYLE
                window.SetWindowStyle();

                var contentWindow = window.CreateStyledWindow();

        // WINDOW POSITION

                double heightScaling = window.Height - contentWindow.Height;
                double widthScaling = window.Width - contentWindow.Width;
                double convertedX = mainCanvas.Width * (((window.PositionX - 
displayOffset) * 1000) / displayWidth);
                double convertedY = 300 - (window.PositionY * 1000);

                if (convertedX <= (window.Width / 2)) convertedX = (window.Width / 2);
                else if (convertedX + (window.Width / 2) > mainCanvas.Width) { 
convertedX = mainCanvas.Width - (window.Width / 2); }

                if (convertedY < 100) convertedY = 100;
                else if (convertedY > 350) convertedY = 350;

                if (window.AnimationStateVal == 3)
                {
                    contentWindow.Background = new SolidColorBrush(Colors.Red);
                    convertedY = -50;
                }

                double windowPositionX = ( convertedX + ( widthScaling / 2 ) );

                AddPositionMarker( window, window.WindowID, windowPositionX );

                Canvas.SetLeft(contentWindow, windowPositionX - (window.Width / 2));
                Canvas.SetTop(contentWindow, ( convertedY + ( heightScaling / 2 ) ) );

                mainCanvas.Children.Add( contentWindow );
            }
        }

        List<Color> colorList = new List<Color>(){ Colors.Red, Colors.Blue, 
Colors.Green, Colors.Yellow, Colors.Salmon,
                                                    Colors.Lime, Colors.Indigo, 
Colors.SandyBrown, Colors.HotPink,
                                                    Colors.Azure, Colors.DarkOrange, 
Colors.Olive, Colors.Teal };
        Dictionary<int, Color> colorRef = new Dictionary<int, Color>();
        private void AddPositionMarker(ContentWindow window, int ID, double position)
        {
            Color markerCol = Colors.Black;

            if (window.MarkerColor == Colors.Black)
            {
                markerCol = GetColorFromList();
                window.MarkerColor = markerCol;
            }
            else
            {
                markerCol = window.MarkerColor;
            }

            double ellipseWidth = 150;
            Ellipse ellipse = new Ellipse() { Height = ellipseWidth/3, Width = 
ellipseWidth };
            ellipse.Fill = new SolidColorBrush(markerCol);
            Canvas.SetTop(ellipse, 20 );
            Canvas.SetLeft(ellipse, (position - ellipseWidth / 2 ));

            mainCanvas.Children.Add(ellipse);
        }

        internal Color GetColorFromList()
        {
            Color color = Colors.Black;

            color = colorList.FirstOrDefault();
            colorList.Remove(color);
            colorList.Add(color);
```

```
            return color;
        }

// ########################

        double trajectoryWindowHeight = 550;
        double trajectoryWindowWidth = 1000;
        double trajectoryWindowPosX = 1400;
        double trajectoryWindowPosZ = 30;
        double maxTrackingDepth = 6200;

        private void DrawTrajectoryMaps(List<trajectoryStruct> trajectoryList)
        {
            DrawBorder();
            DrawTargets( targetDict );

            foreach (trajectoryStruct trajectory in trajectoryList)
            {
                Point[]                         convertedPoints                         =
ConvertToDisplaySpace(trajectory.Trajectory);
                DrawTrajectoryLine(convertedPoints);
            }

            foreach (var position in personPositionsList)
            {
                Point[] point = new Point[1];
                point[0] = new Point(position.X, position.Z);
                DrawRedPoint( ConvertToDisplaySpace( point ) );
            }
        }

        private Point[] ConvertToDisplaySpace( Point[] points )
        {
            Point[] convertedPoints = new Point[ points.Length ];

            for (int i = 0; i <= points.Length - 1; i++ )
            {
                Point point = points[i];
                double ratioX = ( point.X * 1000 ) / displayWidth;
                double ratioZ = ( point.Y * 1000 ) / maxTrackingDepth;
                double    pointX    =    (trajectoryWindowWidth    *    ratioX)    +
trajectoryWindowPosX;
                double    pointZ    =    (trajectoryWindowHeight    *    ratioZ)    +
trajectoryWindowPosZ;
                convertedPoints[i] = new Point( pointX, pointZ );
            }

            return convertedPoints;
        }

        private void DrawBorder()
        {
            SolidColorBrush borderBrush = Brushes.Blue;
            double strokeThickness = 5;

            Line top = new Line();
            top.Stroke = borderBrush;
            top.StrokeThickness = strokeThickness;
            top.X1 = trajectoryWindowPosX;
            top.X2 = trajectoryWindowPosX + trajectoryWindowWidth;
            top.Y1 = top.Y2 = trajectoryWindowPosZ;
            mainCanvas.Children.Add(top);

            Line left = new Line();
            left.Stroke = borderBrush;
            left.StrokeThickness = strokeThickness;
            left.X1 = left.X2 = trajectoryWindowPosX;
            left.Y1 = trajectoryWindowPosZ;
            left.Y2 = trajectoryWindowPosZ + trajectoryWindowHeight;
            mainCanvas.Children.Add( left );

            Line right = new Line();
            right.Stroke = borderBrush;
            right.StrokeThickness = strokeThickness;
            right.X1 = right.X2 = trajectoryWindowPosX + trajectoryWindowWidth;
            right.Y1 = trajectoryWindowPosZ;
            right.Y2 = trajectoryWindowPosZ + trajectoryWindowHeight;
```

```
            mainCanvas.Children.Add( right );

            Line bottom = new Line();
            bottom.Stroke = borderBrush;
            bottom.StrokeThickness = strokeThickness;
            bottom.X1 = trajectoryWindowPosX;
            bottom.X2 = trajectoryWindowPosX + trajectoryWindowWidth;
            bottom.Y1 = bottom.Y2 = trajectoryWindowPosZ + trajectoryWindowHeight;
            mainCanvas.Children.Add( bottom );
        }

        private void DrawTargets(Dictionary<int, List<targetStruct>> targetDict)
        {
            if (targetDict.Count > 1)
            {
                List<targetStruct> gapList = new List<targetStruct>( targetDict[1] );
                List<targetStruct> targetList = new List<targetStruct>( targetDict[2]
);

                foreach( var gap in gapList)
                {
                    Point[] targetPoint = new Point[2];
                    double halfWidth = gap.Width / 2;
                    targetPoint[0]   =   new   Point(gap.Position.X   -   halfWidth,
gap.Position.Z);
                    targetPoint[1]   =   new   Point(gap.Position.X   +   halfWidth,
gap.Position.Z);
                    DrawGap( ConvertToDisplaySpace(targetPoint) );
                }

                foreach (var target in targetList)
                {
                    Point[] targetPoint = new Point[1];
                    targetPoint[0] = new Point(target.Position.X, target.Position.Z);
                    DrawRedPoint(ConvertToDisplaySpace(targetPoint));
                }
            }
        }

        private void DrawTrajectoryLine(Point[] convertedPoints)
        {
            double strokeThickness = 5;
            Line trajectory = new Line();

            trajectory.Stroke = Brushes.Green;
            trajectory.StrokeThickness = strokeThickness;
            trajectory.X1 = convertedPoints[0].X;
            trajectory.Y1 = convertedPoints[0].Y;
            trajectory.X2 = convertedPoints[convertedPoints.Length - 1].X;
            trajectory.Y2 = convertedPoints[convertedPoints.Length - 1].Y;

            mainCanvas.Children.Add( trajectory );
        }

        private void DrawRedPoint(Point[] points)
        {
            Point point = points[0];
            Ellipse ellipse = GetRedEllipse();
            Canvas.SetLeft(ellipse, point.X - (ellipse.Width / 2));
            Canvas.SetTop(ellipse, point.Y - (ellipse.Width / 2));
            mainCanvas.Children.Add(ellipse);
        }

        private void DrawGap(Point[] points)
        {
            double strokeThickness = 5;
            Line gap = new Line();

            gap.Stroke = Brushes.Green;
            gap.StrokeThickness = strokeThickness;
            gap.X1 = points[0].X;
            gap.Y1 = points[0].Y;
            gap.X2 = points[points.Length - 1].X;
            gap.Y2 = points[points.Length - 1].Y;

            mainCanvas.Children.Add(gap);
        }
```

```
// ########################

        private void DrawToCanvas1(List<ColorSpacePoint> points)
        {
            this.bodyPointsCanvas1.Children.Clear();

            if( points.Count() > 0 )
            {
                foreach (ColorSpacePoint point in points)
                {
                    Ellipse ellipse = GetRedEllipse();

                    if (point.X > 0 && point.Y > 0)
                    {
                        ///CONVERT POSITION TO CANVAS
                        Double convX = canv1Width * ( point.X / this.cam1RefWidth );
                        Double convY = canv1Height * ( point.Y / this.cam1RefHeight );

                        ///SET POSITION AND ADD TO CANVAS
                        Canvas.SetLeft(ellipse, convX - (ellipse.Width / 2));
                        Canvas.SetTop(ellipse, convY - (ellipse.Height / 2));

                        this.bodyPointsCanvas1.Children.Add(ellipse);
                    }
                }
            }
        }

// ########################

        private void DrawToCanvas2(List<ColorSpacePoint> points)
        {
            this.bodyPointsCanvas2.Children.Clear();

            if (points.Count() > 0)
            {
                foreach (ColorSpacePoint point in points)
                {
                    Ellipse ellipse = GetRedEllipse();

                    if (point.X > 0 && point.Y > 0)
                    {
                        ///CONVERT POSITION TO CANVAS
                        Double convX = canv2Width * (point.X / this.cam2RefWidth);
                        Double convY = canv2Height * (point.Y / this.cam2RefHeight);

                        ///SET POSITION AND ADD TO CANVAS
                        Canvas.SetLeft(ellipse, convX - (ellipse.Width / 2));
                        Canvas.SetTop(ellipse, convY - (ellipse.Height / 2));

                        bodyPointsCanvas2.Children.Add(ellipse);
                    }
                }
            }
        }

// ########################

        private Ellipse GetRedEllipse()
        {
            Ellipse ellipse = new Ellipse
            {
                Width = 20,
                Height = 20,
                Fill = Brushes.Red
                //,Opacity = 0.1
            };

            return ellipse;
        }

        /// <summary>
        /// GETTERS
        /// </summary>

        private void GetViewsFrameRefs()
```

```
        {
            double[] frameRefs = this.modelsHandler.ViewsHandler.GetFrameRefs();

            this.cam1RefDepth = frameRefs[0];
            this.cam1RefHeight = frameRefs[1];
            this.cam1RefWidth = frameRefs[2];
            this.cam2RefDepth = frameRefs[3];
            this.cam2RefHeight = frameRefs[4];
            this.cam2RefWidth = frameRefs[5];

            SetMainReferenceFrame(cam1RefDepth, cam1RefHeight, cam1RefWidth);
        }

        /// <summary>
        /// SETTERS
        /// </summary>

        internal void SetAllCanvas(Canvas bodyCanvas1, Canvas bodyCanvas2, Canvas
mainBodyCanvas , Canvas backgroundCanvas)
        {
            this.bodyPointsCanvas1 = bodyCanvas1;
            this.canv1Height = bodyCanvas1.Height;
            this.canv1Width = bodyCanvas1.Width;

            this.bodyPointsCanvas2 = bodyCanvas2;
            this.canv2Height = bodyCanvas2.Height;
            this.canv2Width = bodyCanvas2.Width;

            this.mainCanvas = mainBodyCanvas;
            this.mainCanvHeight = mainBodyCanvas.Height;
            this.mainCanvWidth = mainBodyCanvas.Width;

            this.backgroundCanvas = backgroundCanvas;
            this.backgroundCanvasHeight = backgroundCanvas.Height;
            this.backgroundCanvasWidth = backgroundCanvas.Width;
        }

        internal void SetMainReferenceFrame(double refFrameDepth, double
refFrameHeight, double refFrameWidth)
        {
            this.refFrameDepth = refFrameDepth;
            this.refFrameHeight = refFrameHeight;
            this.refFrameWidth = refFrameWidth;
        }
    }
}
```

ContentWindow

```
using System;
using System.Collections.Generic;
using System.Linq;
using System.Text;
using System.Threading.Tasks;
using System.Windows.Media.Media3D;
using global::System.Windows.Controls;
using System.IO;
using System.Windows.Media;

namespace Models
{
    public class ContentWindow
    {
        private bool USING_STUDY_LAYOUT = false;

        public WindowStyleHelper styleHelper;

        private bool updated = false;

        private int windowID;
        private int groupSize = 1;

        private double positionX, positionZ, nextPosX, positionY = 0;
        private double overridePositionX = 0;
        private int width, height = 0;
```

```
        private double lower, upper = 0;

        private bool client1Bool = false, client2Bool = false;
        private bool leftFront = false;
        private bool leftMid = false;
        private bool leftRear = false;
        private bool rightFront = false;
        private bool rightMid = false;
        private bool rightRear = false;

        private string animationState;
        private double animationStateValue;
        private Dictionary<string, double> animationStatesMap;
        private string contentString;
        private string loadedContentString;
        private string userStateString;
        private Color markerColor = Colors.Black;

        private string adaptionState;
        private bool adaptedBool;
        private bool userInChannel = false;

        private System.Timers.Timer contentChangeTimer;
        private double contentChangeInterval = 15000;

        private bool timeout = false;
        private double ADAPTATION_TIMEOUT = 40;

        public ContentWindow(int groupID, Point3D position)
        {
            this.windowID = groupID;
            PositionX = position.X;
            NextPosX = position.X;
            OverridePositionX = PositionX;

            Height = 180;
            Width = 200;

            ContentString = "NEW WINDOW";
            LoadedContentString = LoadContentString();

            animationStatesMap = new Dictionary<string, double>();
            animationStatesMap.Add("none", 0);
            animationStatesMap.Add("background", 1);
            animationStatesMap.Add("hidden", 2);
            animationStatesMap.Add("positionMarker", 3);

            AnimationState = "none";
            AnimationStateVal = animationStatesMap[ AnimationState ];

            AdaptationState = "none";
            AdaptedBool = false;

            Upper = PositionX + (Width / 2);
            Lower = PositionX - (Width / 2);

            styleHelper = new WindowStyleHelper( this );

            // TIMEOUT CALLBACK FOR CONTENT CHANGE
            this.contentChangeTimer    =    new    System.Timers.Timer    {    Interval    =
contentChangeInterval };
            this.contentChangeTimer.Elapsed += contentChangeTimer_Elapsed;
            this.contentChangeTimer.Start();
        }

        private bool twoPages = false;

        private         void         contentChangeTimer_Elapsed(object         sender,
System.Timers.ElapsedEventArgs e)
        {
            LoadedContentString = LoadContentString();
            twoPages = true;
            this.contentChangeTimer.Stop();
        }

        int pageNumber = 1;
```

```
        private string LoadContentString()
        {
            string filename = @"C:\Users\psxjrbu.AD\Documents\ContentWindowText";
            string extension = "Content" + pageNumber.ToString() + ".txt";
            filename = Path.Combine( filename, extension );

            string content = File.ReadAllText( filename );

            pageNumber++;

            return content;
        }

        double minMovementTol = 0.09;
        static double defaultWindowSpeed = 0.015;
        double windowSpeed = defaultWindowSpeed;
        double absMovement = 0;
        double reqMovement = 0;
        double sign = 0;

        DateTime endTime;

        double posDisplay = 0;
        double posUser = 0;

        internal void Update(Point3D position, Person person, string _animationState,
double _lower, double _upper, string WINDOW_ADAPT_STATE)
        {
            AdaptationState = WINDOW_ADAPT_STATE;

            if (animationState == "hidden" || animationState == "backgorund")
                contentChangeTimer.Stop();
            else if ( twoPages != true )
                contentChangeTimer.Start();

            //if (AdaptationState != "none")
            //    adaptationBool = true;

            ContentString = person.Name;
            UserStateString = person.UserState;
            Client1Bool = person.Client1;
            Client2Bool = person.Client2;
            LeftFront = person.LeftFront;
            LeftMid = person.LeftMid;
            LeftRear = person.LeftRear;
            RightFront = person.RightFront;
            RightMid = person.RightMid;
            RightRear = person.RightRear;

            if (USING_STUDY_LAYOUT)
                ContentString = loadedContentString;

            AnimationState = _animationState;
            AnimationStateVal = animationStatesMap[AnimationState];

            Upper = _upper;
            Lower = _lower;

            if( position.X < 0 || position.X > 5 )
            {
                Updated = true;
                return;
            }

            posDisplay = (PositionX * 1000);
            posUser = (position.X * 1000);

            // USER IN CHANNEL --> HAS LIMITED WIDTH TO TRACK USER
            // IF "NORMAL" BEHAVIOUR HAS NOT BEEN RETURNED THIS WILL LIMIT THE RESPONSE
OF THE WINDOW
            // THE "USER CHANNEL" REDUCES THE REPSONSIVENESS OF THE WINDOW

            //if ((posDisplay - Width) < posUser && posUser < (posDisplay + Width))
            //    UserInChannel = true;
            //else
            //    UserInChannel = false;
```

```
            if( AdaptationState != "none")
            {
                if (endTime.Second == 0)
                    endTime = DateTime.Now;

                if (AdaptationState == "constant")
                {
                    //INSERT DELAY AND THEN SET NEXT X POS
                    if (AdaptedBool && UserInChannel)
                    {
                        Timeout = false;
                        AdaptedBool = false;
                    }
                    else if (Timeout)
                    {
                        NextPosX = OverridePositionX;
                        AnimationState = "none";
                        Upper = 0;
                        Lower = 0;
                        if (PositionX == NextPosX)
                        {
                            AdaptedBool = true;
                        }
                    }
                    else if (!AdaptedBool && !Timeout)
                    {
                        NextPosX = position.X;
                    }
                }
                else if (AdaptationState == "targeted")
                {
                    // AFTER TIMER REVERT TO NORMAL
                    //||
                    if  ((UserInChannel)  ||  (DateTime.Now.Subtract(endTime).Seconds  >
ADAPTATION_TIMEOUT))
                    {
                        OverridePositionX = position.X;
                        NextPosX = position.X;
                    }
                    else
                        NextPosX = OverridePositionX;
                }
            }
            else
                NextPosX = position.X;

            PositionY = person.Height;
            PositionZ = position.Z;

            double movement = NextPosX - PositionX;
            absMovement = Math.Abs( movement );
            if( absMovement >= minMovementTol )
                reqMovement = absMovement;

            if (absMovement > 5 * minMovementTol)
                windowSpeed = 1.5 * defaultWindowSpeed;
            else if (absMovement > 3 * minMovementTol)
                windowSpeed = 1.5 * defaultWindowSpeed;
            else windowSpeed = defaultWindowSpeed;

            sign = (movement >= 0) ? 1 : -1;

            Updated = true;
        }

        public void CalculateDrawPosition()
        {
            if ( reqMovement > 0 )
            {
                if (reqMovement < windowSpeed)
                {
                    PositionX = NextPosX;
                    reqMovement = 0;
                }
                else
                {
                    PositionX += sign * windowSpeed;
```

```
                reqMovement -= windowSpeed;
            }
        }
        else
        {
            reqMovement = 0;
        }
    }

//########################
    //STYLE

    public void SetWindowStyle()
    {
        styleHelper.SetWindowStyle( this );
    }

    public Grid CreateStyledWindow()
    {
        return styleHelper.CreateStyledWindow( this );
    }

//########################
    //FIELDS

    public int WindowID
    {
        get { return this.windowID; }
        set
        {
            if ( this.windowID != value )
                this.windowID = value;
        }
    }

    public double PositionX
    {
        get { return this.positionX; }
        set
        {
            if (this.positionX != value)
                this.positionX = value;
        }
    }

    public double PositionY
    {
        get { return this.positionY; }
        set
        {
            if (this.positionY != value)
                this.positionY = value;
        }
    }

    public double PositionZ
    {
        get { return this.positionZ; }
        set
        {
            if (this.positionZ != value)
            this.positionZ = value;
        }
    }

    public double NextPosX
    {
        get { return this.nextPosX; }
        set
        {
            if (this.nextPosX != value)
                this.nextPosX = value;
        }
    }

    public double OverridePositionX
    {
```

```
    get { return this.overridePositionX; }
    set
    {
        if (this.overridePositionX != value)
            this.overridePositionX = value;
    }
}

public int Width
{
    get { return this.width; }
    set
    {
        if (this.width != value)
            Updated = true;
            this.width = value;
    }
}

public int Height
{
    get { return this.height; }
    set
    {
        if (this.height != value)
            Updated = true;
            this.height = value;
    }
}

public bool Updated
{
    get { return this.updated; }
    set
    {
        if (this.updated != value)
            this.updated = value;
    }
}

public DateTime EndTime
{
    get { return this.endTime; }
    set
    {
        if (this.endTime != value)
            this.endTime = value;
    }
}

public Color MarkerColor
{
    get { return this.markerColor; }
    set
    {
        if (this.markerColor != value)
            this.markerColor = value;
    }
}

public double Lower
{
    get { return this.lower; }
    set
    {
        if (this.lower != value)
            this.lower = value;
    }
}

public double Upper
{
    get { return this.upper; }
    set
    {
        if (this.upper != value)
            this.upper = value;
```

```
    }
}

public bool Client1Bool
{
    get { return this.client1Bool; }
    set { this.client1Bool = value; }
}

public bool Client2Bool
{
    get { return this.client2Bool; }
    set { this.client2Bool = value; }
}

public bool LeftFront
{
    get { return this.leftFront; }
    set { this.leftFront = value; }
}

public bool LeftMid
{
    get { return this.leftMid; }
    set { this.leftMid = value; }
}

public bool LeftRear
{
    get { return this.leftRear; }
    set { this.leftRear = value; }
}

public bool RightFront
{
    get { return this.rightFront; }
    set { this.rightFront = value; }
}

public bool RightMid
{
    get { return this.rightMid; }
    set { this.rightMid = value; }
}

public bool RightRear
{
    get { return this.rightRear; }
    set { this.rightRear = value; }
}

public string AnimationState
{
    get { return this.animationState; }
    set
    {
        if (animationState != value)
            this.animationState = value;
    }
}

public double AnimationStateVal
{
    get { return this.animationStateValue; }
    set
    {
        if (animationStateValue != value)
            this.animationStateValue = value;
    }
}

public bool AdaptedBool
{
    get { return this.adaptedBool; }
    set
    {
        if (adaptedBool != value)
```

```
                this.adaptedBool = value;
            }
        }

        public bool Timeout
        {
            get { return this.timeout; }
            set
            {
                if (timeout != value)
                    this.timeout = value;
            }
        }

        public bool UserInChannel
        {
            get { return this.userInChannel; }
            set
            {
                if (userInChannel != value)
                    this.userInChannel = value;
            }
        }

        public string AdaptationState
        {
            get { return this.adaptionState; }
            set
            {
                if (adaptionState != value)
                    this.adaptionState = value;
            }
        }

        public string ContentString
        {
            get { return this.contentString; }
            set
            {
                if (contentString != value)
                    this.contentString = value;
            }
        }

        public string LoadedContentString
        {
            get { return this.loadedContentString; }
            set
            {
                if (loadedContentString != value)
                    this.loadedContentString = value;
            }
        }

        public string UserStateString
        {
            get { return this.userStateString; }
            set
            {
                if (userStateString != value)
                    this.userStateString = value;
            }
        }

        public bool UsingStudyLayout
        {
            get { return this.USING_STUDY_LAYOUT; }
        }
    }
}
```

CSVHandler

```
using System;
using System.Collections.Generic;
```

```
using System.IO;
using System.Linq;
using System.Text;
using System.Threading.Tasks;

namespace Models
{
    class CSVHandler
    {
 //       private string filepath = @"R:\7 - 4th year\02 - User Studies\03 - User Study 
2\User Study Data";
        private string filepath = @"C:\Data";
        private StringBuilder csvString = new StringBuilder();

        public CSVHandler( string _filename )
        {
            filepath = Path.Combine(filepath, _filename);
        }

        //private int userBatchCounter = 0;

        //public void IncrementFilepath()
        //{
        //    userBatchCounter++;
        //    filepath.Remove(filepath.Length);
        //    filepath = filepath + userBatchCounter.ToString();
        //}

        public CSVHandler( string _filename, string[] headers )
        {
            filepath = Path.Combine(filepath, _filename);
            csvString.AppendLine(string.Join(",", headers));
        }

        public CSVHandler( string _append, string _filename, string[] headers)
        {
            filepath = Path.Combine(filepath, _append);
            filepath = Path.Combine(filepath, _filename);
            csvString.AppendLine(string.Join(",", headers));
        }

        public void CSVHeaders( string[] headers )
        {
            csvString.AppendLine(string.Join(",", headers));
        }

        public void AppendOutputData( double[] inputArray )
        {
            csvString.AppendLine( string.Join(",", inputArray));
        }

        public void OutputToFile()
        {
            String csvStringCopy = csvString.ToString();
            try
            {
                File.AppendAllText(filepath, csvStringCopy);
            }
            catch (Exception)
            {
                throw;
            }
            csvString.Clear();
        }
    }
}
```

GroupsHelper

```
using System;
using System.Collections.Generic;
using System.Linq;
using System.Text;
using System.Threading.Tasks;
using System.Windows.Media.Media3D;
```

```
namespace Models
{
    public class GroupsHelper
    {
        Dictionary<int, Point3D> groupPositions = new Dictionary<int, Point3D>();

        public GroupsHelper(){ }

        internal void AssignGroupPosition(Dictionary<double, Person> personDicitonary)
        {
            groupPositions = new Dictionary<int,Point3D>();

            foreach( Person person in personDicitonary.Values )
            {
                int groupID = person.Group;
                Point3D position = person.Position;

                if (!groupPositions.ContainsKey(groupID))
                {
                    groupPositions.Add(groupID, position);
                }
                else
                {
                    Point3D currentPos = groupPositions[groupID];
                    groupPositions[groupID] = new Point3D(
                                            (currentPos.X + position.X)/2,
                                            (currentPos.Y + position.Y)/2,
                                            (currentPos.Z + position.Z)/2 );
                }
            }

            //Console.WriteLine(  "GROUPS  "  +  personDicitonary.Count  +  "  "  +
groupPositions.Count );
        }


//##############################
        // MEMBERS

        public Dictionary<int, Point3D> GroupPositionsDict
        {
            get { return this.groupPositions; }
        }
    }
}
```

HAMMER

```
using System;
using System.Collections.Generic;
using System.Linq;
using System.Text;
using System.Threading.Tasks;
using System.Windows.Media.Media3D;

namespace Models
{
    class HAMMER
    {
        private double interactionZoneTol = 1.5;
        private double movementTol = 0.1;
        private double orientationTolDEG = 50;

        Dictionary<string, Point3D> predictionMap;
        Dictionary<string, List<double>> confidenceMap;
        List<string> hammerModelsList = new List<string>() { "towards", "interact",
"observe", "away", "leave", "left", "right" };

        private Point3D position = new Point3D();
        private Point3D previousPosition = new Point3D();
        private double velocity = 0;
        private double movementDirection = 0;
        private double orientation = 0;
```

```
    public HAMMER()
    {
        predictionMap = new Dictionary<string, Point3D>();

        predictionMap.Add( hammerModelsList[0], new Point3D() );
        predictionMap.Add( hammerModelsList[1], new Point3D() );
        predictionMap.Add( hammerModelsList[2], new Point3D() );
        predictionMap.Add( hammerModelsList[3], new Point3D() );
        predictionMap.Add( hammerModelsList[4], new Point3D() );
        predictionMap.Add( hammerModelsList[5], new Point3D() );
        predictionMap.Add( hammerModelsList[6], new Point3D() );

        confidenceMap = new Dictionary<string, List<double>>();

        List<double> confList = new List<double>();

        confidenceMap.Add( hammerModelsList[0], confList );
        confidenceMap.Add( hammerModelsList[1], confList );
        confidenceMap.Add( hammerModelsList[2], confList );
        confidenceMap.Add( hammerModelsList[3], confList );
        confidenceMap.Add( hammerModelsList[4], confList );
        confidenceMap.Add( hammerModelsList[5], confList );
        confidenceMap.Add( hammerModelsList[6], confList );
    }

    internal void Models( Point3D position, double orientation )
    {
        Position = position;
        Velocity = CalculateVelocity();
        Orientation = orientation;

        double zDiff = previousPosition.Z - position.Z;
        double xDiff = previousPosition.X - position.X;
        movementDirection = Math.Atan2( zDiff, xDiff) - (Math.PI / 2);

        double oriDEG = orientation / Math.PI * 180;

        Point3D prevPosition = PreviousPosition;
        double incrementX = (Velocity * Math.Sin(movementDirection));
        double incrementZ = Math.Abs((Velocity * Math.Cos(movementDirection)));

        if (incrementX < movementTol)
            incrementX = movementTol;
        if (incrementZ < movementTol)
            incrementZ = movementTol;

    // GENERATE PREDICTIONS
        Towards(prevPosition, incrementX, incrementZ);
        Intertact(prevPosition);
        Observe(prevPosition);
        Away(prevPosition, incrementX, incrementZ, oriDEG );
        Leave(prevPosition, incrementX, incrementZ, oriDEG );
        Left(prevPosition, incrementZ, oriDEG);
        Right(prevPosition, incrementZ, oriDEG);
    }

//###########################
//MODELS

    Point3D prediction;

    private void Towards(Point3D prevPosition, double incX, double incZ)
    {
        double x = prevPosition.X + incX;
        double y = prevPosition.Y;
        double z = prevPosition.Z - incZ;

        //Console.Write(" T: " + Math.Round(x, 2));

        prediction = new Point3D(x, y, z);
        predictionMap["towards"] = prediction;
    }

    private void Intertact(Point3D prevPosition)
    {
        if (prevPosition.Z <= interactionZoneTol)
            predictionMap["interact"] = prevPosition;
```

```
        }

        private void Observe(Point3D prevPosition)
        {
            if (prevPosition.Z > interactionZoneTol)
                predictionMap["observe"] = prevPosition;
        }


        private void Away(Point3D prevPosition, double incX, double incZ, double
oriDEG)
        {
            double x = 0, y = 0, z = 0;
            if (-orientationTolDEG < oriDEG && oriDEG < orientationTolDEG)
            {
                x = prevPosition.X + incX;
                y = prevPosition.Y;
                z = prevPosition.Z + incZ;
            }

            prediction = new Point3D(x, y, z);
            predictionMap["away"] = prediction;
        }

        private void Leave(Point3D prevPosition, double incX, double incZ, double
oriDEG)
        {
            double x = 0, y = 0, z = 0;

            if (oriDEG < -orientationTolDEG || oriDEG > orientationTolDEG)
            {
                x = prevPosition.X + incX;
                y = prevPosition.Y;
                z = prevPosition.Z + incZ;
            }

            prediction = new Point3D(x, y, z);
            predictionMap["leave"] = prediction;
        }

        private void Left(Point3D prevPosition, double incX, double oriDEG)
        {
            double x = prevPosition.X - incX;
            double y = prevPosition.Y;
            double z = prevPosition.Z;

            prediction = new Point3D(x, y, z);
            predictionMap["left"] = prediction;
        }

        private void Right(Point3D prevPosition, double incX, double oriDEG)
        {
            double x = prevPosition.X + incX;
            double y = prevPosition.Y;
            double z = prevPosition.Z;

            prediction = new Point3D(x, y, z);
            predictionMap["right"] = prediction;
        }

    //####################
    // CALCULATE STATE

        internal string GetState()
        {
            string state = "no state";

            foreach ( var model in predictionMap )
            {
                Point3D prediction = model.Value;

                double confidence = ConfidenceFunction( prediction, Position );

                confidenceMap[model.Key].Insert( 0, confidence );

                //Console.WriteLine( model.Key + " " + Math.Round( confidence, 2)  );
            }
```

```
            double maxConf = 0;
            var allkeys = new List<string>(confidenceMap.Keys);
            foreach (var modelName in allkeys)
            {
                List<double> confList = confidenceMap[modelName];
                double confRate = 0;

                confRate = ( confList[0] + confList[1] ) / 2;
                confidenceMap[modelName]  =  new  List<double>()  {  confList[0]  ,
confList[1] , confList[2] };

                if (confRate >= maxConf)
                {
                    maxConf = confRate;
                    state = modelName;
                }
            }

            PreviousPosition = Position;

            return state;
        }

        private double ConfidenceFunction( Point3D prediction, Point3D position )
        {
            double confidence = 0;
            double diffX = prediction.X - position.X;
            double diffZ = prediction.Z - position.Z;

            double separation = (Math.Sqrt((diffX * diffX) + (diffZ * diffZ)));

            confidence = 1 / separation;

            return confidence;
        }

    //#########################
    // HELPER METHODS

        List<double> speedSmoothing = new List<double>();
        int smoothingInt = 3;
        internal double CalculateVelocity()
        {
            double deltaX = PreviousPosition.X - Position.X;
            double deltaZ = PreviousPosition.Z - Position.Z;
            speedSmoothing.Insert( 0, Math.Sqrt((deltaX * deltaX) + (deltaZ * deltaZ))
);

            if( speedSmoothing.Count == smoothingInt )
                speedSmoothing.RemoveAt( smoothingInt - 1 );

            double velocity = 0;
            for (int i = 0; i <= ( speedSmoothing.Count - 1 ); i++)
            {
                velocity += speedSmoothing[i];
            }

            return ( velocity / smoothingInt );
        }

    //##########################
    // FIELDS

        private Point3D Position
        {
            get { return this.position; }
            set
            {
                if (this.position != value)
                    this.position = value;
            }
        }

        private double Orientation
        {
            get { return this.orientation; }
```

```
            set
            {
                if (this.orientation != value)
                    this.orientation = value;
            }
        }

        private Point3D PreviousPosition
        {
            get { return this.previousPosition;  }
            set
            {
                if (this.previousPosition != value)
                    this.previousPosition = value;
            }
        }

        public double Velocity
        {
            get { return this.velocity; }
            set
            {
                if (this.velocity != value)
                    this.velocity = value;
            }
        }

        public Dictionary<string, List<double>> ConfidenceMap
        {
            get { return new Dictionary<string, List<double>>( this.confidenceMap ); }
        }

        public List<string> HammerModelsList
        {
            get { return new List<string>( this.hammerModelsList ); }
        }
    }
}
```

MODELLING

```
using System;
using System.Collections.Generic;
using System.Linq;
using System.Text;
using System.Threading.Tasks;
using System.Windows;
using System.Windows.Media.Media3D;

namespace Models
{
    class MODELLING
    {
        List<trajectoryStruct> trajectoryList;
        Dictionary<string, double> confidenceMap;
        List<Point3D> targetPoints;

        Point3D position = new Point3D();
        Point3D previousPosition = new Point3D();
        double direction = 0;

        double movementTolerance = 0.15;

        targetStruct predictedTarget = new targetStruct { };
        private int predictedTargetNumber = 0;

        private bool initialized = false;

        public MODELLING()
        {
            trajectoryList = new List<trajectoryStruct>();
            confidenceMap = new Dictionary<string, double>();
            TargetPoints = new List<Point3D>();

            confidenceMap["simpleModel"] = 0;
```

```
            confidenceMap["funcitonModel"] = 0;
            confidenceMap["curveFitting"] = 0;
        }

        internal void CalculateModels(Point3D position, Dictionary<int,
List<targetStruct>> targetDict )
        {
            Position = position;

            if (CalculateDistance(Position, PreviousPosition) < movementTolerance)
                return;

            if (initialized)
            {
                List<targetStruct> gapList = targetDict[1];
                List<targetStruct> targetList = targetDict[2];

                trajectoryList.Clear();

                Direction = CalculateDirection(PreviousPosition, Position);

                SimpleModels(position, gapList, targetList);

                SelectPredictionTarget( gapList );
            }

            PreviousPosition = Position;
        }

        List<double> approachRate = new List<double>();
        List<double> distToTarget = new List<double>() { 100, 100, 100, 100 };
        List<double> dirToTarget = new List<double>();

        internal void SimpleModels(Point3D position, List<targetStruct> gapList,
List<targetStruct> targetList)
        {
            dirToTarget.Clear();
            approachRate.Clear();

            TargetPoints = CalculateSimpleTargets(gapList, targetList);

            int count = 0;
            foreach (Point3D target in TargetPoints)
            {
                double directionTo = CalculateDirection(Position, target);
                dirToTarget.Insert(count, directionTo);
                double distance = CalculateDistance(Position, target);
                approachRate.Insert(count, (distToTarget[count] - distance));
                distToTarget[count] = distance;

                count++;
            }
        }

        private void SelectPredictionTarget(List<targetStruct> gapList)
        {
            PredictedTargetNumber = TargetConfidenceFuncton();
            int targetInt = PredictedTargetNumber;

            Console.Write( "TARGET " + targetInt);

            if (targetInt != 0)
            {
                double leftGapWidth = gapList.LastOrDefault().Width;

                switch (targetInt)
                {
                    case (1):
                        PredictedTargetStruct = new targetStruct { Position = new
Point3D(0.3, 0, 0), Width = leftGapWidth };
                        break;

                    case (2):
                        PredictedTargetStruct = new targetStruct { Position = new
Point3D(0.3, 0, 0), Width = leftGapWidth };
                        break;
```

```
                    case (3):
                        PredictedTargetStruct  =  new  targetStruct  {  Position  =  new
Point3D(2.5, 0, 0), Width = 1 };
                        break;

                    case (4):
                        PredictedTargetStruct  =  new  targetStruct  {  Position  =  new
Point3D(2.5, 0, 0), Width = 1 };
                        break;
                }
            }
        }

        private int TargetConfidenceFuncton()
        {
            int targetInt = 0;

            double closestDir = dirToTarget.Aggregate((x, y) => Math.Abs(x - Direction)
< Math.Abs(y - Direction) ? x : y);
            int indexOfDir = dirToTarget.IndexOf(closestDir);

            double closestDist = approachRate.Max();
            int indexOfDist = approachRate.IndexOf(closestDist);

            // TODO => CONSTRUCT ADDITIONAL CONFIDENCE FUNCITON MODELS

            if (indexOfDir == indexOfDist)
                targetInt = indexOfDist + 1;

            // TODO

            return targetInt;
        }

//##################
    // CONSTRUCT TARGETS

        List<Point3D> targetPointsList = new List<Point3D>();
        private   List<Point3D>   CalculateSimpleTargets(List<targetStruct>   gapList,
List<targetStruct> targetList)
        {
            Point3D point2 = new Point3D();
            Point3D point3 = new Point3D();

            if (targetPointsList.Count > 0)
            {
                point2 = targetPointsList[1];
                point3 = targetPointsList[2];
            }

            targetPointsList.Clear();

            // ADD POINT AT LEFT OF DISPLAY
            targetPointsList.Add(new Point3D(0.3, 0, 0.5));

            //ADD POINT BEHIND LEFT CLUSTER
            List<double> leftCluster = (from targetStruct gap in gapList
                                        where gap.Position.X > 0.8 && gap.Position.X <
2.5
                                        select gap.Position.X).ToList();

            double leftPointX = (leftCluster.Sum() / leftCluster.Count());

            if (leftCluster.Count > 0)
                targetPointsList.Add(new Point3D(leftPointX, 0, 1.5));
            else
                targetPointsList.Add(point2);

            //ADD POINT AT RIGHT END OF DISPLAY
            List<double> rightTargets = (from target in targetList
                                         where target.Position.X > 2.2
                                         select target.Position.X).ToList();

            double rightPointX = rightTargets.Sum() / rightTargets.Count();

            if (rightTargets.Count > 0)
                targetPointsList.Add(new Point3D(rightPointX, 0, 0.5));
```

```
            else
                targetPointsList.Add(point3);

            //ADD OBSERVE POINT
            targetPointsList.Add(new Point3D(3.5, 0, 3.5));

            return targetPointsList;
        }

//##################
    //HELPER METHODS

        static double _PI = Math.PI;
        private double CalculateDirection( Point3D start, Point3D end )
        {
            double diffX = (end.X - start.X);
            double diffZ = (start.Z - end.Z);
            double angle = Math.Tanh(diffX / diffZ);
            double returnAngle = 0;
            if (diffZ < 0)
            {
                if (diffX < 0)
                    returnAngle = -1 * (_PI - angle);
                else if (diffX > 0)
                    returnAngle = _PI + angle;
            }
            else
                returnAngle = angle;

            return returnAngle;
        }

        private double CalculateDistance(Point3D start, Point3D end)
        {
            double diffX = start.X - end.X;
            double diffZ = start.Z - end.Z;
            return ( Math.Sqrt( ( diffX * diffX ) + ( diffZ * diffZ ) ) );
        }

        double toDEG = 180 / Math.PI;
        internal void PrintPrediciton()
        {
            Console.WriteLine();

            int count = 0;
            foreach (Point3D point in targetPoints)
            {
                count++;
                Console.WriteLine(count    +    "    "    +    point.X    +    "    "    +
Math.Round(CalculateDistance(Position, point) * toDEG, 2));
            }

            Console.WriteLine();

            foreach (double dir in distToTarget)
            {
                Console.WriteLine(Math.Round(dir, 2));
            }

            Console.WriteLine();

            Console.WriteLine("SELECTED " + PredictedTargetNumber + " " + Direction *
toDEG);
        }

//##################
    // GETTERS && SETTERS

        public int PredictedTargetNumber
        {
            get { return this.predictedTargetNumber; }
            set
            {
                if (value != this.predictedTargetNumber)
                    this.predictedTargetNumber = value;
            }
        }
```

```
        public targetStruct GetPredictionTargetStruct()
        {
            return new targetStruct() { Position = new Point3D(0.3, 0, 0), Width = 0.5
};
        }

        private targetStruct PredictedTargetStruct
        {
            get { return this.predictedTarget; }
            set { this.predictedTarget = value; }
        }

        private Point3D Position
        {
            get { return this.position; }
            set
            {
                if (value != this.position)
                    this.position = value;
            }
        }

        private Point3D PreviousPosition
        {
            get { return this.previousPosition; }
            set
            {
                if (value != this.previousPosition)
                {
                    this.previousPosition = value;
                    initialized = true;
                }
            }
        }

        private double Direction
        {
            get { return this.direction; }
            set
            {
                if (value != this.direction)
                    this.direction = value;
            }
        }

        private List<Point3D> TargetPoints
        {
            get { return this.targetPoints; }
            set
            {
                if (value != this.targetPoints)
                    this.targetPoints = value;
            }
        }
    }
}
```

ModelsHandler

```
using System;
using System.Collections.Generic;
using System.Linq;
using System.Text;
using System.Threading.Tasks;

namespace Models
{
    public class ModelsHandler
    {
        private volatile bool viewsSetBool = true;
        private volatile bool personUpdatedBool = true;

        private PersonHandler personHandler;
        private ViewsHandler viewsHandler;
```

```
        public ModelsHandler()
        {
            personHandler = new PersonHandler(this);
            viewsHandler = new ViewsHandler( this );
        }

//  #####################
        //  MEMBERS

        public ViewsHandler ViewsHandler
        {
            get { return this.viewsHandler; }
        }

        public PersonHandler PersonHandler
        {
            get { return this.personHandler; }
        }

//  #####################
        // FIELDS

        public bool ViewsSetBool
        {
            get{    return this.viewsSetBool;   }
            set
            {
                if( this.viewsSetBool != value )
                    this.viewsSetBool = value;
            }
        }

        public bool AllPersonsUpdatedBool
        {
            get{    return this.personUpdatedBool;  }
            set
            {
                if (this.personUpdatedBool != value)
                    this.personUpdatedBool = value;
            }
        }
    }
}
```

Person

```
using Microsoft.Kinect;
using System;
using System.Collections.Generic;
using System.Linq;
using System.Text;
using System.Threading.Tasks;
using System.Windows;
using System.Windows.Media.Media3D;

namespace Models
{
    public class Person
    {
        private MODELLING predicitonModels;
        private HAMMER hammer;
        private CSVHandler csvHandler;
        private string filename;

        private int personID;
        private string personName;

        private List<string> hammerModelsList;

        private Point3D previousPosition = new Point3D();
        private Point3D position = new Point3D();
        private double orientation = 0;
        private double velocity = 0;
        private double height = 0;
```

```
        private string userState = "observe";

        private bool client1 = false, client2 = false;
        private bool moving = false;
        private bool leftFront = false;
        private bool leftMid = false;
        private bool leftRear = false;
        private bool rightFront = false;
        private bool rightMid = false;
        private bool rightRear = false;

        private Dictionary<JointType, Point3D> bodyPointsDict1;
        private List<ColorSpacePoint> csPointsList1;

        private Dictionary<JointType, Point3D> bodyPointsDict2;
        private List<ColorSpacePoint> csPointsList2;

        private Dictionary<JointType, Point3D> bodyPointsDict3;
        private List<ColorSpacePoint> csPointsList3;

        private Dictionary<JointType, Point3D> convertedBodyPointsDict;
        private Dictionary<JointType, Point3D> smoothedPointsDict;
        private Dictionary<JointType, List<Point3D>> smoothingDict;
        private List<ColorSpacePoint> convertedCSPoints;

        private bool updated = false, convertedData = false;

        private int group = 0;

        public Person(int personID, string personName, Dictionary<JointType, Point3D>
_convertedBodyPointsDict, bool RECORD_USER_DATA )
        {
            this.TRACK_USER_BEHAVIOUR = RECORD_USER_DATA;

            this.personID = personID;
            this.personName = personName;
            predicitonModels = new MODELLING();
            hammer = new HAMMER();
            this.hammerModelsList = hammer.HammerModelsList;

            filename = DateTime.Now.ToString("dd_MM_yyyy_hh_mm_ss") + " userData" +
personID.ToString() + ".csv";
            csvHandler = new CSVHandler(filename, new string[] { "TimeStamp", "X", "Z",
"Orientation",
                                                    hammerModelsList[0],
hammerModelsList[1], hammerModelsList[2],
                                                    hammerModelsList[3],
hammerModelsList[4], hammerModelsList[5],
                                                    hammerModelsList[6] });

            bodyPointsDict1 = new Dictionary<JointType, Point3D>();
            bodyPointsDict2 = new Dictionary<JointType, Point3D>();
            bodyPointsDict3 = new Dictionary<JointType, Point3D>();
            csPointsList1 = new List<ColorSpacePoint>();
            csPointsList2 = new List<ColorSpacePoint>();
            csPointsList3 = new List<ColorSpacePoint>();
            convertedBodyPointsDict    =    new    Dictionary<JointType,    Point3D>(
_convertedBodyPointsDict);
            smoothedPointsDict          =          new          Dictionary<JointType,
Point3D>(_convertedBodyPointsDict);
            smoothingDict = new Dictionary<JointType, List<Point3D>>();

            Position = CalculatePosition(convertedBodyPointsDict);
            Orientation = CalculateOrientation(convertedBodyPointsDict);

            Updated = true;
        }

        internal void Update( string clientID,
                              Dictionary<JointType, Point3D> bodyPointsDict,
                              List<ColorSpacePoint> csPointsList,
                              Dictionary<JointType,                           Point3D>
_convertedBodyPointsDict,
                              Dictionary<int, List<targetStruct>> targetList,
                              int dataCounter,
                              float inOrientation )
        {
```

```
            ClientTracking( clientID );

            if (clientID == "CLIENT1")
            {
                this.bodyPointsDict1 = bodyPointsDict;
                this.csPointsList1 = csPointsList;
            }
            else if (clientID == "CLIENT2")
            {
                this.bodyPointsDict2 = bodyPointsDict;
                this.csPointsList2 = csPointsList;
            }
            else if (clientID == "CLIENT3")
            {
                this.bodyPointsDict3 = bodyPointsDict;
                this.csPointsList3 = csPointsList;
            }

            //this.convertedBodyPointsDict             =             SmoothBodyPoints(
_convertedBodyPointsDict );
            this.convertedBodyPointsDict = _convertedBodyPointsDict;

            Position = CalculatePosition(convertedBodyPointsDict);
            Orientation = CalculateOrientation(convertedBodyPointsDict);
            Velocity = hammer.Velocity;
            Height = convertedBodyPointsDict[JointType.Head].Y;

            TrackingConfidence( Position );

            RotationCalculation( clientID, inOrientation );

// #### MODELS ####

        //########################
            // HAMMER MODELS

            ++hammerCounter;
            if (hammerCounter >= hammerDelay)
            {
                hammerCounter = 0;
                hammer.Models(Position, Orientation);
            }

            if (!initialiseHammer)
            {
                UserState = hammer.GetState();
            }
            initialiseHammer = false;

            PreviousPosition = Position;

            //########################
            // PREDICITON MODELS

            ++modellingCounter;
            if (modellingCounter >= modellingDelay)
            {
                modellingCounter = 0;
                predicitonModels.CalculateModels(Position, targetList);
            }

            if (personID == 13)
                predicitonModels.PrintPrediciton();

        //#########################

// #### END ####

        // MAPPING THE INTERACTION AREA

            if (TRACK_USER_BEHAVIOUR && dataCounter > dataDelay)
            {
                dataDelay = dataCounter;
                TrackPositionToFile(  dataCounter,  personID,  Position,  Orientation,
hammer.ConfidenceMap );
            }
```

```
            Updated = true;
        }

        bool initialiseHammer = true;
        int hammerCounter, hammerDelay = 15;
        int modellingCounter, modellingDelay = 15;
        int dataDelay = 0;
        int counter = 0;

// ####  DATA ANLYSIS ####

        bool TRACK_USER_BEHAVIOUR = false;
        int numberOfPoints = -1;
        int outputCounter = 0;

        double[] areaData = new double[12];

        private  void  TrackPositionToFile(int  dataCounter,  int  personID,  Point3D
position, double orientation, Dictionary<string, List<double>> confidenceMap)
        {
            double positionX = position.X;
            double positionZ = position.Z;
            double hmrTowards = confidenceMap[hammerModelsList[0]].FirstOrDefault();
            double hmrInteract = confidenceMap[hammerModelsList[1]].FirstOrDefault();
            double hmrObserve = confidenceMap[hammerModelsList[2]].FirstOrDefault();
            double hmrAway = confidenceMap[hammerModelsList[3]].FirstOrDefault();
            double hmrLeave = confidenceMap[hammerModelsList[4]].FirstOrDefault();
            double hmrLeft = confidenceMap[hammerModelsList[5]].FirstOrDefault();
            double hmrRight = confidenceMap[hammerModelsList[6]].FirstOrDefault();

            if (0 < positionX && 0 < positionZ && positionX < 6 && positionZ < 6)
            {
                areaData[0] = dataCounter;
                areaData[1] = positionX;
                areaData[2] = positionZ;
                areaData[3] = orientation;
                areaData[4] = hmrTowards;
                areaData[5] = hmrInteract;
                areaData[6] = hmrObserve;
                areaData[7] = hmrAway;
                areaData[8] = hmrLeave;
                areaData[9] = hmrLeft;
                areaData[10] = hmrRight;

                outputCounter++;

                csvHandler.AppendOutputData(areaData);
            }

            if (outputCounter >= 5)
            {
                csvHandler.OutputToFile();
            }
        }

        //internal void TrackPositionToFile(Point3D position)
        //{
        //    double positionX = position.X;
        //    double positionZ = position.Z;

        //    if (0 < positionX && 0 < positionZ && positionX < 6 && positionZ < 6)
        //    {
        //        areaData[0] = positionX;
        //        areaData[1] = positionZ;
        //        csvHandler.AppendOutputData(areaData);
        //        outputCounter++;
        //    }

        //    if (outputCounter == numberOfPoints)
        //        csvHandler.OutputToFile();
        //}

        internal void OutputData()
        {
            if (TRACK_USER_BEHAVIOUR && outputCounter > 50 )
            {
                csvHandler.OutputToFile();
```

```
                Console.WriteLine("OUTPUT USER " + ID + " DATA TO FILE");
            }
        }

// #### END ####

        int smoothingInt = 6;
        private Dictionary<JointType, Point3D> SmoothBodyPoints(Dictionary<JointType,
Point3D> convertedBodyPointsDict)
        {
            foreach (var joint in convertedBodyPointsDict)
            {
                if (!smoothingDict.ContainsKey(joint.Key))
                {
                    smoothingDict[joint.Key] = new List<Point3D>();
                    smoothingDict[joint.Key].Add(joint.Value);

                    smoothedPointsDict[joint.Key] = joint.Value;
                }
                else
                {
                    if (smoothingDict[joint.Key].Count >= smoothingInt)
                    {
                        smoothingDict[joint.Key].RemoveAt(smoothingInt - 1);
                    }

                    smoothingDict[joint.Key].Insert(0, joint.Value);
                }
            }

            foreach (var joint in smoothingDict)
            {
                double x = 0, y = 0, z= 0;

                foreach( var point in joint.Value )
                {
                    x += point.X;
                    y += point.Y;
                    z += point.Z;

                    if (point == joint.Value.Last())
                    {
                        int count = joint.Value.Count;
                        x = x / count;
                        y = y / count;
                        z = z / count;

                        smoothedPointsDict[joint.Key] = new Point3D( x, y, z );
                    }
                }
            }

            return smoothedPointsDict;
        }


    //#########################
    // HELPER METHODS

        List<Point3D> positionSmoothing = new List<Point3D>();
        internal     Point3D     CalculatePosition(Dictionary<JointType,     Point3D>
convertedBodyPointsDict)
        {
            Point3D position = new Point3D();

            if (convertedBodyPointsDict.ContainsKey(JointType.SpineBase))
                position = convertedBodyPointsDict[JointType.SpineBase];
            else if (convertedBodyPointsDict.ContainsKey(JointType.SpineMid))
                position = convertedBodyPointsDict[JointType.SpineMid];
            else if (convertedBodyPointsDict.ContainsKey(JointType.Head))
                position = convertedBodyPointsDict[JointType.Head];

            positionSmoothing.Insert(0, position);

            if (positionSmoothing.Count >= smoothingInt)
            {
                positionSmoothing.RemoveAt(positionSmoothing.Count - 1);
```

```
                if (positionSmoothing.Count > smoothingInt)
                    positionSmoothing.RemoveAt(positionSmoothing.Count - 1);
            }

            foreach (Point3D point in positionSmoothing)
            {
                position.X += point.X;
                position.Y += point.Y;
                position.Z += point.Z;
            }

            int dataPoints = positionSmoothing.Count + 1;    // point == position -
DUPLICATION - ( LIST[0] ) => ( +1 )
            Point3D finalPosition = new Point3D(
                                    position.X / dataPoints,
                                    position.Y / dataPoints,
                                    position.Z / dataPoints);

        // IF USER MAS MOVED MORE IN "smoothingInt" FRAMES THAN PREVIOUS FRAME

            double movement = Math.Abs(positionSmoothing[0].X - finalPosition.X);
            double vel = Math.Abs(Velocity);

            if (movement < vel ) Moving = true;
            else Moving = false;

            return finalPosition;
        }

        double angle1, angle2, angle3 = 0;
        double angle = 0;
        bool reverse = false;
        double reverseTol = 65;

        private double RotationCalculation(string clientID, float inOrientation)
        {
            if (angle <= -reverseTol || angle >= reverseTol)
                reverse = true;
            else
                reverse = false;

            double inOrientationDeg = (double) inOrientation;// / Math.PI * 180;

            if (inOrientationDeg > 1000)
                return 0;
            //Console.WriteLine("REJECTED " + inOrientationDeg );
            else
            {
                if (clientID == "CLIENT1")
                {
                    angle1 = inOrientationDeg - 29;
                    if (reverse)
                    {
                        if (angle <= -reverseTol)
                            angle1 -= 180;
                        else if (angle >= reverseTol)
                            angle1 += 180;
                    }
                    //Console.WriteLine(reverse.ToString()  + " " + Math.Round(angle,
2) + " " + Math.Round(angle1, 2));
                    angle = (angle + angle1) / 2;
                }

                if (clientID == "CLIENT2")
                {
                    angle2 = inOrientationDeg + 29;
                    if (reverse)
                    {
                        if (angle <= -reverseTol)
                            angle2 -= 180;
                        else if (angle >= reverseTol)
                            angle2 += 180;
                    }
                    //Console.WriteLine( reverse.ToString() + " " + Math.Round(angle,
2) + " " + Math.Round(angle2, 2));

                    angle = (angle + angle2) / 2;
```

```
            }

            if (clientID == "CLIENT3")
            {
                angle3 = inOrientationDeg;
                if (reverse)
                {
                    if (angle <= -reverseTol)
                        angle2 -= 180;
                    else if (angle >= reverseTol)
                        angle2 += 180;
                }
                //Console.WriteLine(Math.Round((angle1  -  angle2),  2)  +  "  "  +
Math.Round(angle1, 2) + " " + Math.Round(angle2, 2) + " " + Math.Round(angle3, 2));
                angle = (angle + angle3) / 2;
            }
        }

        //Console.WriteLine( Math.Round( angle, 2 ) );

        //if (-130 <= inOrientationDeg && inOrientationDeg <= -25)
        //{ Console.WriteLine("1"); }
        //else if (-25 < inOrientationDeg && inOrientationDeg <= 0 )
        //{ Console.WriteLine("2"); }
        //else if (0 < inOrientationDeg && inOrientationDeg < 25)
        //{ Console.WriteLine("3"); }
        //else if (25 <= inOrientationDeg && inOrientationDeg <= 130 )
        //{ Console.WriteLine("4"); }

        return angle;
    }

    List<double> angleSmoothing = new List<double>();
    List<Point3D> leftShoulderList = new List<Point3D>();
    List<Point3D> rightShoulderList = new List<Point3D>();
    double leftX, leftZ, rightX, rightZ = 0;

    internal    double    CalculateOrientation(Dictionary<JointType,    Point3D>
convertedBodyPointsDict)
    {
        leftShoulderList.Insert(                                            0,
convertedBodyPointsDict[JointType.ShoulderLeft] );
        rightShoulderList.Insert(                                           0,
convertedBodyPointsDict[JointType.ShoulderRight] );

        if( leftShoulderList.Count >= 7 )
            leftShoulderList.RemoveAt(6);
        if (rightShoulderList.Count >= 7)
            rightShoulderList.RemoveAt(6);

        foreach( Point3D point in leftShoulderList )
        {
            leftX += point.X;
            leftZ += point.Z;
        }
        foreach (Point3D point in rightShoulderList)
        {
            rightX += point.X;
            rightZ += point.Z;
        }

        leftX = leftX / leftShoulderList.Count;
        leftZ = leftZ / leftShoulderList.Count;
        rightX = rightX / rightShoulderList.Count;
        rightZ = rightZ / rightShoulderList.Count;

        double diffX = rightX - leftX;
        double diffZ = rightZ - leftZ;
        double viewingAngle = 0;

        if (diffX == 0)
            if( angleSmoothing.Count != 0 )
                viewingAngle = angleSmoothing[0];
            else
            {
                viewingAngle = 0;
                angleSmoothing.Insert(0, viewingAngle);
```

```
                }
            else
                viewingAngle = Math.Atan(diffZ / diffX);

        // ENSURE A WIDE ANGLE VIEW OF THE USER FOR BEST DATA
            angleSmoothing.Insert( 0, viewingAngle );

            double returnAngle = 0;
            int count = angleSmoothing.Count;

            if ( count >= 5 )
                angleSmoothing.RemoveAt(4);

            foreach (var angle in angleSmoothing)
                returnAngle += angle;
            returnAngle = returnAngle / count;

            return ( returnAngle );
        }

// TO DO - GET ROTATION DICTIONARY FROM CLIENTS

        //List<double> rotationSmoothing = new List<double>();
        //internal double CalculateRotation( Dictionary<JointType, Point3D> 
convertedBodyPointsDict )
        //{
        //    double returnAngle = 0;

        //   Point3D SpineShoulder = convertedBodyPointsDict[JointType.SpineShoulder];
        //    Point3D SpineMid = convertedBodyPointsDict[JointType.SpineMid];
        //    Point3D SpineBase = convertedBodyPointsDict[JointType.SpineBase];

        //    return returnAngle;
        //}

        private double CalculateVelocity()
        {
            double finalVelocity = 0;

            Point3D position = Position;
            Point3D prevPos = PreviousPosition;

            double diffX = position.X - prevPos.X;
            double diffZ = position.Z - prevPos.Z;

            finalVelocity = Math.Sqrt( ( diffX * diffX ) + ( diffZ * diffZ ) );

            if (finalVelocity > 0.5)
                finalVelocity = 0;

            int direction = diffX > 0 ? 1 : -1;

            return ( finalVelocity * direction );
        }

        string previousInput = "";
        private void ClientTracking(string clientID)
        {
            if (clientID == previousInput)
                Client1 = Client2 = false;

            if (clientID == "CLIENT1")
                Client1 = true;

            if (clientID == "CLIENT2")
                Client2 = true;

            previousInput = clientID;
        }

        private void TrackingConfidence(Point3D position)
        {
            double x = position.X;
            double z = position.Z;

            LeftFront = LeftMid = LeftRear = RightFront = RightMid = RightRear = false;
```

```
            if( x < 0.5 && z < 2 )
                LeftFront = true;
            if( x < 0.5 && z > 1.5 && z < 3.5 )
                LeftMid = true;
            if( x < 0.5 && z > 3 )
                LeftRear = true;

            if( x > 4 && z < 2 )
                RightFront = true;
            if( x > 4 && z > 1.5 && z < 3.5 )
                RightMid = true;
            if( x > 4 && z > 3 )
                RightRear = true;
        }

    //####### BIOMETRICS #########

        //double largestPos = 0;
        //double smallestPos = 100;

        //private bool ComparePosition(double[] idBioData, double[] biometrics)
        //{
        //    Point3D oldPt = new Point3D(idBioData[0], idBioData[1], idBioData[2]);
        //   Point3D newPt = new Point3D(biometrics[0], biometrics[1], biometrics[2]);

        //    double length = CalculatePointsLength( oldPt, newPt);

        //    if (length < smallestPos)
        //        smallestPos = length;
        //    if (length > largestPos)
        //        largestPos = length;

        //    Console.WriteLine("POS " + (largestPos - smallestPos));

        //    if (length < posTol)
        //        return true;
        //    else
        //        return false;
        //}

        //double largestArm = 0;
        //double smallestArm = 100;

        //internal double ArmLength( Dictionary<JointType, Point3D> bodyPointsDict )
        //{
        //    Point3D leftElbow = bodyPointsDict[JointType.ElbowLeft];
        //    Point3D leftShoulder = bodyPointsDict[JointType.ShoulderLeft];

        //    double length = CalculatePointsLength(leftElbow, leftShoulder);

        //    if (length < smallestArm)
        //        smallestArm = length;
        //    if (length > largestArm)
        //        largestArm = length;

        //    Console.WriteLine("ARM " + (largestArm - smallestArm));

        //    return length;
        //}

        //double largestLeg = 0;
        //double smallestLeg = 100;
        //internal double LegLength(Dictionary<JointType, Point3D> bodyPointsDict)
        //{
        //    Point3D leftKnee = bodyPointsDict[JointType.KneeLeft];
        //    Point3D leftHip = bodyPointsDict[JointType.HipLeft];

        //    double length = CalculatePointsLength( leftKnee, leftHip );

        //    if (length < smallestLeg)
        //        smallestLeg = length;
        //    if (length > largestLeg)
        //        largestLeg = length;

        //    Console.WriteLine("LEG " + (largestLeg - smallestLeg));
        //    Console.WriteLine();
        //    return length;
```

```
        //}

        //double bioTol = 50 / 1000;
        //private bool CompareBiometrics(double[] idBioData, double[] biometrics)
        //{
        //    bool x = false;
        //    bool y = false;
        //    bool z = false;
        //    bool arm = false;
        //    bool leg = false;

        //   //Point3D oldPt = new Point3D( idBioData[0], idBioData[1], idBioData[2]);
        //          //Point3D  newPt  =  new  Point3D(biometrics[0],  biometrics[1],
biometrics[2]);

        //    //Console.WriteLine( "SEPARATION " + CalculatePointsLength(oldPt, newPt)
);

        //    for (int i = 0; i <= ( idBioData.Length - 1 ); i++)
        //    {
        //        double idData = idBioData[i];
        //        double bio = biometrics[i];

        //        switch(i)
        //        {
        //            case 0:
        //                if ((idData - posTol) < bio && bio < (idData + posTol))
        //                {
        //                    Console.WriteLine("TOL " + (idData - bio));
        //                    x = true;
        //                }
        //                break;
        //            case 1:
        //                if ((idData - posTol) < bio && bio < (idData + posTol))
        //                    y = true;
        //                break;
        //            case 2:
        //                if ((idData - posTol) < bio && bio < (idData + posTol))
        //                    z = true;
        //                break;
        //            case 3:
        //               if ((idData * (1 - bioTol)) < bio && (idData * (1 + bioTol))
< bio)
        //                    arm = true;
        //                break;
        //            case 4:
        //               if ((idData * (1 - bioTol)) < bio && (idData * (1 + bioTol))
< bio)
        //                    leg = true;
        //                break;
        //        }
        //    }

        //    //Console.WriteLine( "COMPARE " + x + " " + y + " " + z + " " + arm + "
" + leg );

        //    if (x && y && z && arm && leg)
        //        return true;
        //    else if (x && y && z)
        //    {
        //        entryUpdateReq = true;
        //        //Console.WriteLine("PARTIAL");
        //        return true;
        //    }
        //    else
        //        return false;
        //}

        // ############################
        //FIELDS

        public int ID
        {
            get { return this.personID;  }
        }

        public string Name
```

```
{
    get { return this.personName; }
    set
    {
        if ( personName != value )
        this.personName = value;
    }
}

public bool Updated
{
    get { return this.updated; }
    set
    {
        if (this.updated != value)
            this.updated = value;
    }
}

public bool ConvertedDataBool
{
    get { return this.convertedData; }
    set
    {
        if (this.convertedData != value)
            this.convertedData = value;
    }
}

public int Group
{
    get { return this.group; }
    set
    {
        if (this.group != value)
            this.group = value;
    }
}

public bool Client1
{
    get { return this.client1; }
    set { this.client1 = value; }
}

public bool Client2
{
    get { return this.client2; }
    set { this.client2 = value; }
}

public bool Moving
{
    get { return this.moving; }
    set { moving = value; }
}

public bool LeftFront
{
    get { return this.leftFront; }
    set { this.leftFront = value; }
}

public bool LeftMid
{
    get { return this.leftMid; }
    set { this.leftMid = value; }
}

public bool LeftRear
{
    get { return this.leftRear; }
    set { this.leftRear = value; }
}

public bool RightFront
{
```

```
    get { return this.rightFront; }
    set { this.rightFront = value; }
}

public bool RightMid
{
    get { return this.rightMid; }
    set { this.rightMid = value; }
}

public bool RightRear
{
    get { return this.rightRear; }
    set { this.rightRear = value; }
}

// ###########################
//MEMBERS

public Point3D PreviousPosition
{
    get { return this.previousPosition; }
    set
    {
        if (this.previousPosition != value)
            this.previousPosition = value;
    }
}

public Point3D Position
{
    get { return this.position;  }
    set
    {
        if (this.position != value)
            this.position = value;
    }
}

public double Orientation
{
    get { return this.orientation; }
    set
    {
        if (this.orientation != value)
            this.orientation = value;
    }
}

public double Velocity
{
    get { return this.velocity; }
    set
    {
        if (this.velocity != value)
            this.velocity = value;
    }
}

public double Height
{
    get { return this.height; }
    set
    {
        if (this.height < value)
            this.height = value;
    }
}

public string UserState
{
    get { return this.userState; }
    set
    {
        if (this.userState != value)
            this.userState = value;
    }
```

```
        }

        public Dictionary<JointType, Point3D> BodyPointsDict1
        {
            get { return bodyPointsDict1; }
            set
            {
                if (this.bodyPointsDict1 != value)
                    this.bodyPointsDict1 = value;
            }
        }

        public Dictionary<JointType, Point3D> BodyPointsDict2
        {
            get { return bodyPointsDict1; }
            set
            {
                if (this.bodyPointsDict1 != value)
                    this.bodyPointsDict1 = value;
            }
        }

        public Dictionary<JointType, Point3D> ConvertedBodyPointsDict
        {
            get { return convertedBodyPointsDict; }
            set
            {
                if (this.convertedBodyPointsDict != value)
                    this.convertedBodyPointsDict = value;
            }
        }

        public List<ColorSpacePoint> CSPointsList1
        {
            get { return csPointsList1; }
            set
            {
                if (this.csPointsList1 != value)
                    this.csPointsList1 = value;
            }
        }

        public List<ColorSpacePoint> CSPointsList2
        {
            get { return csPointsList2; }
            set
            {
                if (this.csPointsList2 != value)
                    this.csPointsList2 = value;
            }
        }

        public List<ColorSpacePoint> ConvertedPoints
        {
            get { return convertedCSPoints; }
            set
            {
                if (this.convertedCSPoints != value)
                    this.convertedCSPoints = value;
            }
        }

        public targetStruct GetPredictionTargetStruct()
        {
            return predicitonModels.GetPredictionTargetStruct();
        }

        public int GetPredictedTargetNumber()
        {
            return predicitonModels.PredictedTargetNumber;
        }
    }
}
```

PersonHandler

```
using Microsoft.Kinect;
using ServerData;
using System;
using System.Collections.Generic;
using System.Linq;
using System.Text;
using System.Threading;
using System.Threading.Tasks;
using System.Windows.Media.Media3D;

namespace Models
{
    public class PersonHandler
    {
        public bool RECORDING_USER_DATA = false;

        private ModelsHandler modelsHandler;
        private GroupsHelper groupHandler;
        private CSVHandler csvHandler;
        private string filename;

        private Dictionary<ulong, userIDClass> IDDictionary = new Dictionary<ulong,
userIDClass>();
        private Dictionary<double, Person> personDicitonary = new Dictionary<double,
Person>();
        private Dictionary<double, Person> activeUsersDict = new Dictionary<double,
Person>();
        private Dictionary<double, Person> activeUsersDictCopy = new
Dictionary<double, Person>();
        private Dictionary<int, List<targetStruct>> targetDict = new Dictionary<int,
List<targetStruct>>();

        private System.Timers.Timer dataTimer;
        private int dataCounter = 0;
        private int dataInterval = 100; // ms - 10 DATA POINTS PER SECOND

        public PersonHandler( ModelsHandler modelsHandler )
        {
            this.modelsHandler = modelsHandler;
            this.groupHandler = new GroupsHelper();

            //this.csvHandler = new CSVHandler("areaMap.csv", new string[] { "X1",
"Z1", "X2", "Z2", "dX", "XLOW", "XMED", "XHIGH", "dZ", "ZLOW", "ZMED", "ZHIGH" });
            filename = DateTime.Now.ToString("dd_MM_yyyy_hh_mm_ss") +
"AllUserData.csv";
            this.csvHandler = new CSVHandler("AllUsers", filename, new string[] {
"Timestamp", "P", "X", "Z", "P", "X", "Z", "P", "X", "Z", "P", "X", "Z",
                                                                            "P",
"X", "Z", "P", "X", "Z", "P", "X", "Z", "P", "X", "Z" });

            this.dataTimer = new System.Timers.Timer { Interval = dataInterval };
            this.dataTimer.Elapsed += dataTimer_Elapsed;
            this.dataTimer.Start();
        }

        double[] allUserDataArray = new double[31];
        void dataTimer_Elapsed(object sender, System.Timers.ElapsedEventArgs e)
        {
            this.dataCounter++;

            Dictionary<double, Person> userDictCopy = PersonDict;
            List<Person> userList = userDictCopy.Values.OrderBy( o => o.ID ).ToList();
            allUserDataArray[0] = dataCounter;

            int interval = 0;
            foreach (Person person in userList)
            {
                Point3D position = person.Position;
                allUserDataArray[ 1 + ( 3 * interval )] = person.ID;
                allUserDataArray[ 2 + ( 3 * interval )] = position.X;
                allUserDataArray[ 3 + ( 3 * interval )] = position.Z;

                interval ++;
            }
```

```
            csvHandler.AppendOutputData( allUserDataArray );

            if( outputCounter % 10 == 0 )
                csvHandler.OutputToFile();
        }

        public void SetAllUsersUpdateFalse()
        {
            foreach (Person person in activeUsersDict.Values)
                person.Updated = false;

            //foreach (userIDClass idClass in IDDictionary.Values)
            //    idClass.Updated = false;
        }

        public void ResetPersonHandler()
        {
            foreach( var user in activeUsersDict.Values )
                user.OutputData();

            this.personDicitonary.Clear();
            this.activeUsersDict.Clear();
            this.IDDictionary.Clear();
            idCounter = 0;

            modelsHandler.ViewsHandler.ClearWindows();
        }

        bool updateingUsers = false;
        public void UpdatePersonData(
                              string clientID,
                              ulong kinectID,
                              Dictionary<JointType, Point3D> bodyPointsDict,
                              List<ColorSpacePoint> csPointsList,
                              Dictionary<JointType, Point3D> convertedBodyPointsDict,
                              float inOrientation )
        {
            if     (convertedBodyPointsDict[JointType.SpineBase].X     ==     0     &&
convertedBodyPointsDict[JointType.SpineBase].Y == 0)
                return;

            this.updateingUsers = true;

            int personID = GetPersonID( clientID, kinectID, convertedBodyPointsDict );

            if (personID == 0)
            {
                this.updateingUsers = false;
                return;
            }

            Person person = GetPerson( personID, convertedBodyPointsDict );
            person.Update(clientID,           bodyPointsDict,           csPointsList,
convertedBodyPointsDict, targetDict, dataCounter, inOrientation );

            if (person.Group == 0)
                person.Group = person.ID;
                //person.Group = TestGroupings();

            if (activeUsersDict.ContainsKey(personID))
                activeUsersDict[personID] = person;
            else
                activeUsersDict.Add( personID, person );


            // MAPPING THE INTERACTION AREA
            if (MAP_INTERACTION_AREA)
                MapInteractionArea(clientID, person.Position, personID);


            this.updateingUsers = false;
        }

        int idCounter = 0;

        public int GetPersonID( string clientID, ulong kinectID, Dictionary<JointType,
Point3D> convertedPointsDict )
```

```
        {
            int ID = 0;
            bool hasKinectID = false;

            Dictionary<ulong,   userIDClass>   IDDictCopy   =   new   Dictionary<ulong,
userIDClass>(IDDictionary);
            Point3D positionPt = GetPosition( convertedPointsDict );

            //Console.WriteLine(Math.Round(positionPt.X, 2) + " " +
            //                    Math.Round(positionPt.Y, 2) + " " +
            //                    Math.Round(positionPt.Z, 2));

            if  (positionPt.X  <=  0  ||  positionPt.Z  <=  0  ||  positionPt.X  >  6  ||
positionPt.Z > 6)
            {
                if (IDDictCopy.ContainsKey(kinectID) && IDDictCopy[kinectID].Active)
                    return IDDictCopy[kinectID].UserID;
                else
                    return 0;
            }
            else
            {
                if( IDDictCopy.ContainsKey( kinectID) )
                {
                    var userDetails = IDDictCopy[kinectID];
                    hasKinectID = true;

                    if (userDetails.Active)
                    {
                        ID = userDetails.UserID;
                        userDetails.SanityCheckPos(positionPt);

                        List<userIDClass> otherActive = (from activeUser in IDDictCopy
                                                         where
                                                            activeUser.Key          !=
kinectID
                                                                &&
activeUser.Value.UserID != ID
                                                                &&
activeUser.Value.Active
                                                            select
activeUser.Value).ToList();

                    // IF ANOTHER USER ID IS TOO CLOSE - INVALIDATE AND TEST AGAIN
                        foreach (var otherAct in otherActive)
                        {
                            if (otherAct.SanityCheckPos(positionPt))
                            {
                                otherAct.Active = false;
                            }
                        }

                        return ID;
                    }
                    else if (!userDetails.Active)
                    {
                        foreach (var activeID in IDDictCopy)
                        {
                            if (activeID.Key != kinectID)
                            {
                                var activeUser = activeID.Value;

                                if (activeUser.Active)
                                {
                                    if (activeUser.SanityCheckPos(positionPt))
                                    {
                                        userDetails.Active = true;
                                        ID = userDetails.UserID = activeUser.UserID;
                                        userDetails.Position = activeUser.Position;
                                        return ID;
                                    }
                                }
                            }
                        }

                        if (userDetails.UserID == 0)
                        {
```

```
                    userDetails.UserID = ID = ++idCounter;
                }

                userDetails.Active = true;
            }
        }

        if (ID == 0 && !hasKinectID )
        {
            IDDictionary.Add(kinectID, userIDClass.Create(ID, positionPt));
        }
    }

    return 0;
}

class userIDClass
{
    private Point3D position;
    private int userID;
    private bool active;

    private double activePosTol;

    public static userIDClass Create( int _id, Point3D _position )
    {
        return new userIDClass()
        {
            userID = _id,
            activePosTol = 0.2,
            position = new Point3D( _position.X, _position.Y, _position.Z ),
            active = false,
        };
    }

    internal bool SanityCheckPos(Point3D positionPt)
    {
        if (CalculatePointsLength(Position, positionPt) < activePosTol)
        {
            Point3D position = Position;
            double x = (positionPt.X + position.X)/2;
            double y = (positionPt.Y + position.Y)/2;
            double z = (positionPt.Z + position.Z)/2;
            Position = new Point3D( x, y, z );
            return true;
        }
        else return false;
    }

    public double CalculatePointsLength(Point3D pt1, Point3D pt2)
    {
        double diffX = pt1.X - pt2.X;
        double diffY = pt1.Y - pt2.Y;
        double diffZ = pt1.Z - pt2.Z;

        return Math.Sqrt((diffX * diffX) + (diffZ * diffZ));
    }

    public int UserID
    {
        get { return this.userID; }
        set { if (value != 0) this.userID = value; }
    }

    public bool Active
    {
        get { return this.active; }
        set { this.active = value; }
    }

    public Point3D Position
    {
        get { return this.position; }
        set { position = value; }
    }
}
```

```
// ############################
    // DATA ANLYSIS

        bool MAP_INTERACTION_AREA = false;
        int numberOfPoints = 150;

        double[] areaData = new double[10];
        double areaPosX, areaPosZ, maxX, maxZ = 0;
        bool client1Updated = false;
        double posTol = 0.2;

        internal void MapInteractionArea( string clientID, Point3D position, int _id )
        {
            //areaData = new double[12];
            double positionX = position.X;
            double positionZ = position.Z;
            Console.WriteLine(Math.Round(positionX, 2) + " " + Math.Round(positionZ,
2) + " " + outputCounter);

            if( 0 < positionX && 0 < positionZ && positionX < 6 && positionZ < 6 )
            {
                //if (clientID == "CLIENT1")
                //{
                //    areaData[0] = areaPosX = Math.Round(positionX, 2);
                //    areaData[1] = areaPosZ = Math.Round( positionZ, 2);
                //    client1Updated = true;
                //}
                //if (clientID == "CLIENT2" && client1Updated)
                //{
                //    client1Updated = false;
                //    areaData[0] = Math.Round(positionX, 2);
                //    areaData[1] = Math.Round(positionZ, 2);
                //    areaData[2] = Math.Round(positionX, 2);
                //    areaData[3] = Math.Round(positionZ, 2);
                //    areaData[4] = Math.Round(positionX, 2);
                //    areaData[5] = Math.Round(positionZ, 2);
                //    areaData[6] = Math.Round(positionX, 2) - areaPosX;
                //    areaData[7] = Math.Round(positionZ, 2) - areaPosZ;
                //}
                //else if ( clientID == "CLIENT2")
                //{
                //    areaData[2] = Math.Round(positionX, 2);
                //    areaData[3] = Math.Round(positionZ, 2);
                //}
                //csvHandler.AppendOutputData(areaData);
                //outputCounter++;

                if (clientID == "CLIENT1")
                {
                    areaData = new double[12];

                    areaData[0] = areaPosX = Math.Round(positionX, 2);
                    areaData[1] = areaPosZ = Math.Round(positionZ, 2);

                    if (areaPosX > maxX)
                        maxX = areaPosX;
                    if (areaPosZ > maxZ)
                        maxZ = areaPosZ;

                    if (areaPosX != 0 && areaPosZ != 0)
                        client1Updated = true;
                }
                if (clientID == "CLIENT2" && client1Updated)
                {
                    client1Updated = false;

                    areaData[2] = Math.Round(positionX, 2);
                    areaData[3] = Math.Round(positionZ, 2);

                    areaData[4] = Math.Round(positionX, 2) - areaPosX;
                    double dX = Math.Abs(Math.Round(positionX, 2) - areaPosX);

                    if (dX < (posTol / 2))
                        areaData[5] = dX;
                    else if ((posTol / 2) <= dX && dX < posTol)
                        areaData[6] = dX;
                    else
```

```
                        areaData[7] = dX;

                    areaData[8] = Math.Round(positionZ, 2) - areaPosZ;
                    double dZ = Math.Abs(Math.Round(positionZ, 2) - areaPosZ);

                    if (dZ < (posTol / 2))
                        areaData[9] = dZ;
                    else if ((posTol / 2) <= dZ && dZ < posTol)
                        areaData[10] = dZ;
                    else
                        areaData[11] = dZ;

                    csvHandler.AppendOutputData(areaData);
                    outputCounter++;
                }
            }

            if (outputCounter == numberOfPoints)
                csvHandler.OutputToFile();
        }

        int outputCounter = 0;

// ############################

    // FUNCTIONAL METHODS

        string userName = null;
        public   Person   GetPerson(int   personID,   Dictionary<JointType,   Point3D>
convertedBodyPointsDict)
        {
            Person person;

            if (!personDicitonary.ContainsKey(personID))
            {
                person  =  new  Person(personID,  userName,  convertedBodyPointsDict,
this.RECORDING_USER_DATA );
                personDicitonary.Add(personID, person);
            }
            else
                person = personDicitonary[personID];

            if (person.Name == null && userName != null)
            {
                person.Name = userName;
                userName = null;
            }

            return person;
        }

        public void SetUserName( string userNameIN )
        {
            userName = userNameIN;
        }

        public void SetGroupDataToWindows()
        {
            groupHandler.AssignGroupPosition( PersonDict );
            this.modelsHandler.ViewsHandler.UpdateWindows(         GetGroupPositions,
PersonDict, dataCounter );
            modelsHandler.AllPersonsUpdatedBool = true;
        }

        public void FlushInactiveUserIDs( List<ulong> usersToBurn )
        {
            foreach (ulong kinectID in usersToBurn)
            {
                try
                {
                    IDDictionary.Remove(kinectID);
                }
                catch (Exception ex)
                {
                }
            }
```

```
            var inactiveUsers = (from inactive in activeUsersDict
                                 where inactive.Value.Updated == false
                                 select inactive.Key).ToList();

            foreach (var key in inactiveUsers)
            {
                activeUsersDict[key].OutputData();
                activeUsersDict.Remove(key);
            }

            SetAllUsersUpdateFalse();
        }

// ###########################
        // HELPER METHODS

        int group = 0;
        internal int TestGroupings()
        {
            return ++group;
        }

        public double CalculatePointsLength(Point3D pt1, Point3D pt2)
        {
            double diffX = pt1.X - pt2.X;
            double diffY = pt1.Y - pt2.Y;
            double diffZ = pt1.Z - pt2.Z;

            return Math.Sqrt((diffX * diffX) + (diffZ * diffZ));
        }

        internal       Point3D       GetPosition(Dictionary<JointType,       Point3D>
convertedBodyPointsDict)
        {
            Point3D position = new Point3D();

            if (convertedBodyPointsDict.ContainsKey(JointType.SpineBase))
                position = convertedBodyPointsDict[JointType.SpineBase];
            else if (convertedBodyPointsDict.ContainsKey(JointType.SpineMid))
                position = convertedBodyPointsDict[JointType.SpineMid];
            else if (convertedBodyPointsDict.ContainsKey(JointType.Head))
                position = convertedBodyPointsDict[JointType.Head];

            return position;
        }

// ###########################
        // MEMBERS

        public Dictionary<double, Person> PersonDict
        {
            get
            {
                if (!this.updateingUsers)
                    activeUsersDictCopy        =        new        Dictionary<double,
Person>(activeUsersDict);

                return activeUsersDictCopy;
            }
        }

        public Dictionary<int, Point3D> GetGroupPositions
        {
            get { return this.groupHandler.GroupPositionsDict;  }
        }

        public Dictionary<int, List<targetStruct>> TargetDict
        {
            get { return this.targetDict; }
            set { this.targetDict = new Dictionary<int, List<targetStruct>>( value );
}
        }
    }
}
```

TargetStruct

```
using System;
using System.Collections.Generic;
using System.Linq;
using System.Text;
using System.Threading.Tasks;
using System.Windows.Media.Media3D;

namespace Models
{
    public struct targetStruct
    {
        private int type;
        private Point3D position;
        private double width;

        public int Type
        {
            get { return this.type; }
            set { this.type = value; }
        }

        public Point3D Position
        {
            get { return this.position; }
            set { this.position = value; }
        }

        public double Width
        {
            get { return this.width; }
            set { this.width = value; }
        }
    }
}
```

TrajectoryStruct

```
using System;
using System.Collections.Generic;
using System.Linq;
using System.Text;
using System.Threading.Tasks;
using System.Windows;

namespace Models
{
    public struct trajectoryStruct
    {
        Point[] trajectoryPoints;
        double confidence;

        public Point[] Trajectory
        {
            get { return this.trajectoryPoints; }
            set { this.trajectoryPoints = value; }
        }

        public double Confidence
        {
            get { return this.confidence; }
            set { this.confidence = value; }
        }
    }
}
```

ViewsHandler

```
using System;
using System.Collections.Generic;
using System.Linq;
using System.Text;
using System.Threading.Tasks;
using System.Windows.Media.Media3D;
```

```
namespace Models
{
    public class ViewsHandler
    {
    // SMOOTHING PARAMETERS
        double velocityTol = 0.08;
        double windowProxTol = 80;

    // PHYSICAL PARAMETERS
        private double displayWidth = 4350;
        private double displayOffset = 0.05;
        private static double halfWindowWidth = 150;

    // INTERNAL MEMBERS
        ModelsHandler modelsHandler;
        private CSVHandler csvHandler;
        private string filename;
        private bool OUTPUT_DISPLAY_LAYOUT = false;

        Dictionary<int, ContentWindow> windowDicitonary;
        Dictionary<int, ContentWindow> activeWindowDicit;

        Dictionary<int,   List<targetStruct>>   targetDict   =   new   Dictionary<int,
List<targetStruct>>();
        List<targetStruct> targetList = new List<targetStruct>();
        List<targetStruct> gapList = new List<targetStruct>();

        private double cam1refFrameDepth = 0;
        private double cam1refFrameHeight = 0;
        private double cam1refFrameWidth = 0;

        private double cam2refFrameDepth = 0;
        private double cam2refFrameHeight = 0;
        private double cam2refFrameWidth = 0;

        private bool USING_PREDICTION_MODELS = true;
        private string WINDOW_ADAPT_STATE = "none";     //NONE || CONSTANT || TARGETED
        private double REQUIRED_TARGET_SIZE = (4 * halfWindowWidth);
        private double ADAPT_MIN_GROUPSIZE = 2;
        private string WINDOW_ANIMATION_STATE = "background";        //NONE || HIDDEN
|| BACKGROUND

        double minTargetSize = 1;

        public ViewsHandler( ModelsHandler modelsHandler )
        {
            this.modelsHandler = modelsHandler;

            filename     =     DateTime.Now.ToString("dd_MM_yyyy_hh_mm")     +     "
displayLayout.csv";
            this.csvHandler = new CSVHandler( filename, new string[] { "TimeStamp",
                                    "ID",  "X",  "Xlower",  "Xupper",  "Xtarget",  "Z",
"State",
                                    "ID",  "X",  "Xlower",  "Xupper",  "Xtarget",  "Z",
"State",
                                    "ID",  "X",  "Xlower",  "Xupper",  "Xtarget",  "Z",
"State",
                                    "ID",  "X",  "Xlower",  "Xupper",  "Xtarget",  "Z",
"State",
                                    "ID",  "X",  "Xlower",  "Xupper",  "Xtarget",  "Z",
"State",
                                    "ID",  "X",  "Xlower",  "Xupper",  "Xtarget",  "Z",
"State",
                                    "ID",  "X",  "Xlower",  "Xupper",  "Xtarget",  "Z",
"State" });

            this.OUTPUT_DISPLAY_LAYOUT                                                    =
this.modelsHandler.PersonHandler.RECORDING_USER_DATA;

            windowDicitonary = new Dictionary<int, ContentWindow>();
            activeWindowDicit = new Dictionary<int, ContentWindow>();
        }

//############################
        //MANAGE CONTENT WINDOWS
```

```
        List<ContentWindow> reversedWindowList = new List<ContentWindow>();

        Dictionary<int, Point3D> groupPositions = new Dictionary<int,Point3D>();
        Dictionary<double, Person> personDict = new Dictionary<double, Person>();
        public   void   UpdateWindows(Dictionary<int,   Point3D>   InGroupPositions,
Dictionary<double, Person> InPersonDict, int dataCounter )
        {
            foreach (ContentWindow window in windowDicitonary.Values)
                window.Updated = false;

            reversedWindowList.Clear();
            reversedWindowList = (from window in activeWindowDicit
                                  orderby window.Value.PositionX descending
                                  select window.Value).ToList();

            activeWindowDicit = new Dictionary<int, ContentWindow>();

            groupPositions = new Dictionary<int, Point3D>(InGroupPositions);
            personDict = new Dictionary<double, Person>(InPersonDict);

            var orderedPersonList = ( from person in personDict
                                         orderby person.Value.Position.Z ascending
                                         select person.Value ).ToList();

            while( activeWindowDicit.Count < groupPositions.Count )
            {
                foreach (Person person in orderedPersonList)
                {
                    CalculateTargets();
                    int groupNumber = person.Group;
                    TestActiveWindowsClash(groupNumber, groupPositions[groupNumber]);
                }

                // GET ALL PERSONS NOT ASSIGNED TO AN ACTIVE WINDOW
                // ORDER BY DEPTH FROM DISPLAY AND TEST FOR CLASH
                var toDraw = (from groupPos in groupPositions
                              orderby groupPos.Value.Z ascending
                              where !activeWindowDicit.ContainsKey(groupPos.Key)
                              select groupPos).ToList();

                foreach (var groupData in toDraw)
                {
                    CalculateTargets();
                    TestActiveWindowsClash(groupData.Key, groupData.Value);
                }
            }

            if ( OUTPUT_DISPLAY_LAYOUT )
                WriteWindowLayoutToFile( dataCounter );
        }

        internal void TestActiveWindowsClash( int _groupNumber, Point3D _position )
        {
            int groupNumber = _groupNumber;
            Point3D position = _position;
            double deltaZ = 0;

            double from = (position.X * 1000) - halfWindowWidth;
            double to = (position.X * 1000) + halfWindowWidth;

            // FOR EACH WINDOW "TO DRAW" - CHECK IF CLASH WITH ACTIVE WINDOW
            List<ContentWindow> activeWindows = activeWindowDicit.Values.ToList();
            foreach (ContentWindow activeWindow in activeWindows)
            {
                // WINDOW PROX TOL - MULTIPLY BY DELTA-Z - WHAT IS THE PERIPHERAL VIEW
ANGLE OF THE USER
                double depthWindowProxTol = windowProxTol * ( 3 + deltaZ );
                double upper = (activeWindow.PositionX * 1000) + (activeWindow.Width /
2) + depthWindowProxTol;
                double lower = (activeWindow.PositionX * 1000) - (activeWindow.Width /
2) - depthWindowProxTol;

                // IF CLASH SET ANIMATION
                if ( (lower < from) && (from < upper) || (lower < to) && (to < upper)
)
                {
                    //ContentWindow window = GetWindow(groupNumber, position);
```

```
                    Person    person    =    (Person)personDict.Values.Where(entry    =>
entry.Group == groupNumber).FirstOrDefault();
                    CalculateWindowAdaptation(          position,          person,
WINDOW_ANIMATION_STATE, lower, upper, groupNumber);
                    break;
                }
            }

            // IF NO CLASH THEN DRAW
            if (!activeWindowDicit.ContainsKey(groupNumber))
            {
                //ContentWindow window = GetWindow(groupNumber, position);
                Person person = (Person)personDict.Values.Where(entry => entry.Group
== groupNumber).FirstOrDefault();
                CalculateWindowAdaptation(   position,   person,   "none",   0,   0,
groupNumber);
            }
        }

//############################
        //MANAGE ADAPTATIONS

        private int newUserID = 0;
        private void CalculateWindowAdaptation(Point3D position, Person person, string
animationState, double lower, double upper, int groupNumber)
        {
            ContentWindow window = GetWindow(groupNumber, position);

            if (groupPositions.Count >= ADAPT_MIN_GROUPSIZE)
            {
                if (USING_PREDICTION_MODELS)
                {
                    if (!reversedWindowList.Exists(item => item.WindowID == newUserID)
&& person.ID == newUserID)
                    {
                        // NEW USER
                        // FIND PREDICTED TARGET FOR USER - CRETAE WINDOW AT THAT
LOCATION

                        // IF PREDICITON IS NOT MADE YET

                        //Console.WriteLine();

                        //foreach (var win in reversedWindowList)
                        //{
                        //    Console.WriteLine(win.WindowID);
                        //}

                        //Console.WriteLine();

                        //Console.WriteLine("NEW USER " + newUserID);

                        int targetInt = person.GetPredictedTargetNumber();

                        //DEBUG
                        if( person.ID != 3 )
                            targetInt = 1;

                        if (targetInt != 0)
                        {
                            targetStruct target = person.GetPredictionTargetStruct();

                            Console.WriteLine("REQUIRED   "   +   (minTargetSize   -
target.Width) + " AT " + target.Position );

                            window  =  CreateTargetedWindow(window,  target.Position,
target.Width, (minTargetSize - target.Width), groupNumber);
                            //window.Update(position, person, animationState, lower,
upper, "targeted");
                        }
                        else
                        {
                            //TARGET IS NOT RESOLVED WITH ENOUGH CONFIDENCE
                            // RETURN FROM FUNCITON - REMOVE WINDOW FROM WINDOW
DICTIONARY

                            windowDicitonary.Remove(window.WindowID);
```

```
                        return;
                    }
                }

                //if( window.WindowID == newUserID)
                //   window.Update(position, person, animationState, lower, upper,
"targeted");
                //else
                    window.Update(position, person, animationState, lower, upper,
"targeted");
            }
            else
            {
                //ADAPTATION MODELS
                //CALCULATE REQUIREMENTS FOR WINDOW ADAPTATION
                if (WINDOW_ADAPT_STATE != "none")
                {
                    if (WINDOW_ADAPT_STATE == "constant")
                    {
                        //OVERRIDE WINDOW POSITION
                        //STACK WINDOWS ACCORDING TO FURTHEST RIGHT POSITION
                        int count = 0;

                        //if (!reversedWindowList.Exists(item => item.WindowID ==
groupNumber))
                        //    newUserID = groupNumber;

                        foreach (ContentWindow adjWindow in reversedWindowList)
                        {
                            double     adjPosition     =     (displayWidth     -
(halfWindowWidth)) - ((4.1 * halfWindowWidth) * count);
                            Point3D adjUserPosition = new Point3D((adjPosition /
1000), position.Y, position.Z);

                            //GET 'ACTIVE' WINDOW FROM 'ADJWINDOW' ID

                            if     (adjWindow.WindowID     ==     newUserID     &&
adjWindow.WindowID == person.ID)
                            {
                                count--;
                                window = GetWindow(newUserID, position);
                                window.Timeout = false;
                                window.Update(position,  person,  animationState,
lower, upper, "constant");
                            }
                            else if (person.ID == adjWindow.WindowID)
                            {
                                //SET ACIVE WINDOW POSITION
                                adjWindow.OverridePositionX = adjPosition / 1000;
                                adjWindow.Timeout = true;
                                window = GetWindow(groupNumber, position);
                                window.Timeout = true;
                                window.Update(position,  person,  animationState,
lower, upper, "constant");
                            }
                            else
                            {
                                adjWindow.Timeout = true;
                                adjWindow.OverridePositionX = adjPosition / 1000;
                            }

                            count++;
                        }
                    }
                    else if (WINDOW_ADAPT_STATE == "targeted")
                    {
                        //IF WINDOW IS NEW --> SET LOCATION FROM GAP LIST
                        if  (!reversedWindowList.Exists(item  =>  item.WindowID  ==
groupNumber))
                        {
                            Console.WriteLine("TARGETED");
                            Console.WriteLine("NEW USER " + groupNumber);

                            //FIND DIMENSIONS OF LARGEST GAP
                            Point3D gapPosition = new Point3D();
                            double gapWidth = 0;
                            double totalGapWidth = 0;
```

```
                              foreach (targetStruct gap in gapList)
                              {
                                  totalGapWidth += gap.Width;
                                  if (gap.Width > gapWidth)
                                  {
                                      gapWidth = gap.Width;
                                      gapPosition = gap.Position;
                                  }
                              }

                              //IF NOT LARGE ENOUGH GAP --> ADJUST LAYOUT
                              double requiredIncrease = minTargetSize - gapWidth;
                              if (requiredIncrease > 0)
                              {
                                  window = CreateTargetedWindow(window, gapPosition,
gapWidth, requiredIncrease, groupNumber);
                              }

                              window.OverridePositionX = gapPosition.X;
                              window.PositionX = gapPosition.X;
                              window.Update(position, person, animationState, lower,
upper, "targeted");
                          }
                          else
                          {
                              //IF NOT NEW AND INTERACTING --> NORMAL BEHAVIOUR
                              window.Update(position, person, animationState, lower,
upper, "targeted");
                          }
                      }
                  }
                  else
                  {
                      window.Update(position, person, animationState, lower, upper,
"none");
                  }
              }
          }
          else
          {
              window.Update(position, person, animationState, lower, upper, "none");
          }

          AddActiveWindow(groupNumber, window);
      }

      internal  ContentWindow  CreateTargetedWindow(ContentWindow  window,  Point3D
gapPosition, double gapWidth, double requiredIncrease, int groupNumber)
      {
          window.PositionX = gapPosition.X;
          window.OverridePositionX = gapPosition.X;
          reversedWindowList.Add(window);

          List<targetStruct> localGapList = new List<targetStruct>(gapList);

          //SPLIT LEFT / RIGHT LIST
          List<targetStruct> leftGapList = (from gap in localGapList
                                            where gap.Position.X < gapPosition.X
                                            orderby gap.Position.X descending
                                            select gap).ToList();

          List<targetStruct> rightGapList = (from gap in localGapList
                                             where gap.Position.X > gapPosition.X
                                             orderby gap.Position.X ascending
                                             select gap).ToList();

          // IF POSITION < 0.5m => SET ALL GAPS TO RIGHT SIDE
          if (gapPosition.X <= 0.5)
          {
              Console.WriteLine( "TO THE RIGHT" );

              leftGapList.Clear();

              rightGapList = (from gap in localGapList
                              orderby gap.Position.X ascending
                              select gap).ToList();
          }
```

```
            // FIRST TO PROVIDE A SOLUTION
            //COMPARE LEFT AND RIGHT
            targetStruct solutionGap = new targetStruct();
            int counter = 0;

            while (solutionGap.Width == 0)
            {
                double leftWidth = 0, rightWidth = 0;
                double centreLeft = 0, centreRight = 0;

                for (int i = 0; i <= counter; i++)
                {
                    if (i <= (leftGapList.Count - 1))
                    {
                        leftWidth += leftGapList[i].Width;
                        centreLeft = leftGapList[i].Position.X;
                    }
                    if (i <= (rightGapList.Count - 1))
                    {
                        rightWidth += rightGapList[i].Width;
                        centreRight = rightGapList[i].Position.X;
                    }
                }

                if (leftWidth > requiredIncrease && leftWidth > rightWidth)
                {
                    double centre = centreLeft + ((gapPosition.X - centreLeft) / 2);
                    solutionGap.Position = new Point3D(centre, 0, 0);
                    solutionGap.Width  =  ((gapPosition.X  -  centreLeft)  +  (0.5  *
(gapWidth + leftWidth)));
                }
                else if (rightWidth > requiredIncrease)
                {
                    double centre = gapPosition.X + ((centreRight - gapPosition.X) /
2);
                    solutionGap.Position = new Point3D(centre, 0, 0);
                    solutionGap.Width  =  ((centreRight  -  gapPosition.X)  +  (0.5  *
(gapWidth + rightWidth)));
                }
                else if ((leftWidth + rightWidth) > requiredIncrease)
                {
                    double centre = centreLeft + ((centreRight - centreLeft) / 2);
                    solutionGap.Position = new Point3D(centre, 0, 0);
                    solutionGap.Width = (centreRight - centreLeft) + (0.5 * (rightWidth
+ leftWidth));
                }

                counter++;
            }

            // FIND ALL WINDOWS IN SOLUTION GAP
            double gapLower = solutionGap.Position.X - (solutionGap.Width / 2);
            double gapUpper = solutionGap.Position.X + (solutionGap.Width / 2);

            List<ContentWindow>   adaptWindowListReversed   =   (from   wind   in
reversedWindowList
                                                            where   wind.PositionX   >
gapLower && wind.PositionX < gapUpper
                                                            orderby     wind.PositionX
descending
                                                            select wind).ToList();

            // DISTRIBUTE ALL WINDOWS IN SOLUTION GAP
            int count = 0;
            double       gapDistribution       =       solutionGap.Width       /
(adaptWindowListReversed.Count());

            foreach (ContentWindow adjWindow in adaptWindowListReversed)
            {
                double   adjustedPosition   =   (gapUpper   -   ((count   +   0.5)   *
gapDistribution));

                // WINDOW LIST DOES NOT CONTAIN NEW WINDOW
                // CHECK ON MIN_WINDOW_WIDTH ==> STEP OVER
                //if (adjustedPosition > (gapPosition.X - (minTargetSize / 2)) &&
                //    adjustedPosition < (gapPosition.X + (minTargetSize / 2)))
```

```
                if ( USING_PREDICTION_MODELS && adjWindow.WindowID == groupNumber)
                {
                    // PLACE WINDOW AT LEFT HAND END

                    Console.WriteLine("PREDICTED " + gapPosition.X);

                    // REDUCE COUNT TO STACK WINDOWS TO RIGHT
                    count--;

                    adjWindow.PositionX = gapPosition.X;
                    adjWindow.OverridePositionX = gapPosition.X;
                }
                else if (adjWindow.WindowID == groupNumber)
                {
                    // CALCULATED POSITON FALLS WIHTIN GAP FOR NEW WINDOW

                    Console.WriteLine("ADJUSTED " + adjustedPosition);

                    gapPosition.X = adjustedPosition;
                    adjWindow.PositionX = gapPosition.X;
                    adjWindow.OverridePositionX = gapPosition.X;
                }
                else
                {
                    Console.WriteLine("MOVING  "  +  adjWindow.WindowID  +  "  TO  "  +
adjustedPosition);

                    adjWindow.AdaptationState = "targeted";
                    adjWindow.OverridePositionX = adjustedPosition;
                    adjWindow.EndTime = new DateTime();
                }

                count++;
            }

            return window;
        }

//############################
        //DISPLAY LAYOUT

        internal void AddActiveWindow( int inGroupNumber, ContentWindow inWindow )
        {
            if (!activeWindowDicit.ContainsKey(inGroupNumber))
                activeWindowDicit.Add(inGroupNumber, inWindow);
            else
                activeWindowDicit[inGroupNumber] = inWindow;
        }

        public ContentWindow GetWindow(int groupID, Point3D position)
        {
            ContentWindow window;

            if (!windowDicitonary.ContainsKey( groupID ) )
            {
                newUserID = groupID;
                window = new ContentWindow( groupID, position );
                this.windowDicitonary.Add( groupID, window );
            }
            else
                window = this.windowDicitonary[ groupID ];

            return window;
        }

        internal void CalculateTargets()
        {
            targetDict.Clear();
            gapList.Clear();
            targetList.Clear();

            List<double> windows = ( from window in reversedWindowList
                                     orderby window.PositionX ascending
                                     select window.PositionX ).ToList();

            windows.Add( ( displayWidth / 1000 ) );
```

```
            double first = 0, second;
            foreach (var wind in windows)
            {
                second = wind;

                double separation = second - first - ( 2 * halfWindowWidth / 1000 );
                int count = (int) ( separation / minTargetSize );
                int remainder = (int) ( separation % minTargetSize );

                targetStruct gap = new targetStruct();
                gap.Type = 1;
                gap.Position  =  new  Point3D((first  +  (halfWindowWidth  /  1000)  +
(separation / 2)), 0, 1);
                gap.Width = separation;
                gapList.Add( gap );

                double partSeparation = ( separation + remainder ) / count;
                for (int i = 0; i <= (count - 1); i++)
                {
                    targetStruct target = new targetStruct();
                    target.Type = 2;
                    target.Position = new Point3D((first + (partSeparation / 2) + (i *
partSeparation)), 0, 1);
                    target.Width = minTargetSize;

                    targetList.Add(target);
                }

                first = wind;
            }

            targetDict[1] = gapList;
            targetDict[2] = targetList;
        }

        double[] displayLayoutData = new double[73];
        int windowCounter = 0;
        int outputCounter = 0;

        private void WriteWindowLayoutToFile(int dataCounter)
        {
            //outputCounter++;

            Dictionary<int,  ContentWindow>  windowDictCopy  =  new  Dictionary<int,
ContentWindow>( WindowDictionary );
            List<ContentWindow> orderedWindowList = (from window in windowDictCopy
                                                     orderby    window.Value.WindowID
ascending
                                                     select window.Value).ToList();

            displayLayoutData[0] = dataCounter;

            foreach (var window in orderedWindowList)
            {
                int increment = 7 * windowCounter;
                displayLayoutData[1 + increment] = window.WindowID;
                displayLayoutData[2 + increment] = window.PositionX;
                displayLayoutData[3 + increment] = window.PositionZ;
                displayLayoutData[4 + increment] = window.NextPosX;
                displayLayoutData[5 + increment] = window.AnimationStateVal;
                displayLayoutData[6 + increment] = window.Lower;
                displayLayoutData[7 + increment] = window.Upper;

                windowCounter++;
            }

            windowCounter = 0;

            if (dataCounter > outputCounter)
            {
                csvHandler.AppendOutputData(displayLayoutData);
                outputCounter = dataCounter;
            }

            if( dataCounter % 10 == 0 )
                csvHandler.OutputToFile();
```

```
            //if (outputCounter > 100 && orderedWindowList.Count == 0)
            //{
            //    outputCounter = 0;
            //    csvHandler.OutputToFile();
            //    Console.WriteLine("DISPLAY LAYOUT WRITTEN TO FILE");
            //}
        }

        internal void ClearWindows()
        {
            windowDicitonary.Clear();
        }

//############################
        //SET CAMERA REFERENCE FRAMES

        bool client1, client2 = false;

        public void SetViewsData( string ClientID, double[] viewData )
        {
            if (ClientID == "CLIENT1")
            {
                this.cam1refFrameDepth = viewData[0];
                this.cam1refFrameHeight = viewData[1];
                this.cam1refFrameWidth = viewData[2];
                this.client1 = true;
            }
            else if (ClientID == "CLIENT2")
            {
                this.cam2refFrameDepth = viewData[0];
                this.cam2refFrameHeight = viewData[1];
                this.cam2refFrameWidth = viewData[2];
                this.client2 = true;
            }

            /// DEBUG
            this.modelsHandler.ViewsSetBool = true;

            if (client1 && client2)
                this.modelsHandler.ViewsSetBool = true;
        }

// #######################
        // FIELDS

        public double[] GetFrameRefs()
        {
            double[] frameRefs = new double[6];

            frameRefs[0] = this.cam1refFrameDepth;
            frameRefs[1] = this.cam1refFrameHeight;
            frameRefs[2] = this.cam1refFrameWidth;
            frameRefs[3] = this.cam2refFrameDepth;
            frameRefs[4] = this.cam2refFrameHeight;
            frameRefs[5] = this.cam2refFrameWidth;

            return frameRefs;
        }

        public double DisplayWidth
        {
            get { return this.displayWidth; }
        }

        public double DisplayOffset
        {
            get { return this.displayOffset; }
        }

// #######################
        // MEMBERS

        public Dictionary<int, ContentWindow> WindowDictionary
        {
            get { return activeWindowDicit; }
        }
```

```
        public Dictionary<int, List<targetStruct>> GetTargetDict()
        {
            return this.targetDict;
        }
    }
}
```

WindowStyleHelper

```
using System;
using System.Collections.Generic;
using System.Linq;
using System.Text;
using System.Threading.Tasks;
using System.Windows;
using System.Windows.Controls;
using System.Windows.Media;
using System.Windows.Shapes;

namespace Models
{
    public class WindowStyleHelper
    {
        bool usingStyleAnimation = true;

        Dictionary<string, double> windowStyle;

        public WindowStyleHelper(ContentWindow window)
        {
            windowStyle = new Dictionary<string, double>();

            windowStyle.Add("Height", window.Height);
            windowStyle.Add("Width", window.Width);
            windowStyle.Add("Lower", window.Lower);
            windowStyle.Add("Upper", window.Upper);
            windowStyle.Add("Opacity", 1);
        }

        public void SetWindowStyle(ContentWindow window)
        {
            windowStyle["Height"] = window.Height;
            windowStyle["Width"] = window.Width;
            windowStyle["Lower"] = window.Lower;
            windowStyle["Upper"] = window.Upper;
            windowStyle["Rounding"] = 0;
            windowStyle["Opacity"] = 1;

            if (window.AnimationState == "positionMarker")
            {
                windowStyle["Height"] = window.Height * 0.35;
                windowStyle["Width"] = window.Width * 0.35;
                windowStyle["Rounding"] = 0;
            }
            else if (window.AnimationState == "background")
            {
                double scaling = (window.Upper - window.Lower) / 2;
                double center = window.Lower + scaling;
                double adjPosition = (window.PositionX * 1000) - center;
                double ratio = Math.Abs(adjPosition / scaling);
                if (ratio > 1) ratio = 1;

                if (!usingStyleAnimation)
                {
                    // TO LOCK WINDOW POSITION
                    if (adjPosition < 0)
                        window.PositionX = (window.Lower / 1000);
                    if (adjPosition > 0)
                        window.PositionX = (window.Upper / 1000);
                }
                else
                {
                    // TO STYLE FADE WINDOW
                    windowStyle["Opacity"] = 0.5 * ratio;
                    windowStyle["Height"] = window.Height * (0.5 * (0.5 + ratio));
```

```
                    windowStyle["Width"] = window.Width * (0.5 * (0.5 + ratio));
                }
            }
            if (window.AnimationState == "hidden")
            {
                windowStyle["Opacity"] = 0;
            }
        }

        internal Grid CreateStyledWindow( ContentWindow window )
        {
            var contentWindow = new Grid();

        // WINDOW STYLE
            contentWindow.Height = windowStyle["Height"];
            contentWindow.Width = windowStyle["Width"];
            contentWindow.Opacity = windowStyle["Opacity"];
            contentWindow.Background = new SolidColorBrush(Colors.LightSteelBlue);

            if (window.UsingStudyLayout)
            {
                if (window.AnimationState == "positionMarker")
                {
                    contentWindow.Background = new SolidColorBrush(Colors.Red);
                }
                else
                {
                    RowDefinition row = new RowDefinition();
                    row.Height = new GridLength(window.Height);
                    ColumnDefinition col = new ColumnDefinition();
                    col.Width = new GridLength(window.Width);

                    contentWindow.RowDefinitions.Add(row);
                    contentWindow.ColumnDefinitions.Add(col);

                    TextBlock text1 = new TextBlock();
                    text1.FontSize = 15;
                    text1.Text = window.LoadedContentString;
                    text1.HorizontalAlignment                                   =
System.Windows.HorizontalAlignment.Center;
                    Grid.SetRow(text1, 0);
                    Grid.SetColumn(text1, 0);

                    text1.TextWrapping = TextWrapping.Wrap;

                    contentWindow.Children.Add(text1);
                }
            }
            else
            {
                // WINDOW CONTENT
                contentWindow.ShowGridLines = true;

                RowDefinition rowDefinition = new RowDefinition();
                rowDefinition.Height = new GridLength(45);
                RowDefinition rowDefinition1 = new RowDefinition();
                rowDefinition1.Height = new GridLength(45);
                RowDefinition rowDefinition2 = new RowDefinition();
                rowDefinition2.Height = new GridLength(45);

                ColumnDefinition colDef = new ColumnDefinition();
                colDef.Width = new GridLength(25);
                ColumnDefinition colDef2 = new ColumnDefinition();
                colDef2.Width = new GridLength(25);
                ColumnDefinition colDef1 = new ColumnDefinition();
                colDef1.Width     =     new     GridLength((contentWindow.Width     -
colDef.Width.Value - colDef2.Width.Value));

                contentWindow.ColumnDefinitions.Add(colDef);
                contentWindow.ColumnDefinitions.Add(colDef1);
                contentWindow.ColumnDefinitions.Add(colDef2);

                contentWindow.RowDefinitions.Add(rowDefinition);
                contentWindow.RowDefinitions.Add(rowDefinition1);
                contentWindow.RowDefinitions.Add(rowDefinition2);

                // ######################
```

```
                // ROW DEFINITIONS

                // ROW 1
                TextBlock text1 = new TextBlock();
                text1.FontSize = 20;
                text1.Text = window.ContentString;
                text1.HorizontalAlignment                                            =
System.Windows.HorizontalAlignment.Center;
                Grid.SetRow(text1, 0);
                Grid.SetColumn(text1, 1);

                // ROW 2
                TextBlock text2 = new TextBlock();
                text2.FontSize = 20;
                text2.Text = window.UserStateString;
                text2.HorizontalAlignment                                            =
System.Windows.HorizontalAlignment.Center;
                Grid.SetRow(text2, 1);
                Grid.SetColumn(text2, 1);


                // ROW 3
                TextBlock text3 = new TextBlock();
                text3.FontSize = 20;
                text3.Text = window.WindowID.ToString();
                text3.HorizontalAlignment                                            =
System.Windows.HorizontalAlignment.Center;
                Grid.SetRow(text3, 2);
                Grid.SetColumn(text3, 1);

                contentWindow.Children.Add(text1);
                contentWindow.Children.Add(text2);
                contentWindow.Children.Add(text3);

                // TRACKING INDICATORS
                if (window.Client1Bool)
                {
                    var ellipse1 = GetGreenEllipse();
                    if (window.LeftFront)
                        ellipse1.Fill = Brushes.Red;
                    Grid.SetRow(ellipse1, 0);
                    Grid.SetColumn(ellipse1, 0);
                    contentWindow.Children.Add(ellipse1);

                    var ellipse2 = GetGreenEllipse();
                    if (window.LeftMid)
                        ellipse2.Fill = Brushes.Red;
                    Grid.SetRow(ellipse2, 1);
                    Grid.SetColumn(ellipse2, 0);
                    contentWindow.Children.Add(ellipse2);

                    var ellipse3 = GetGreenEllipse();
                    if (window.LeftRear)
                        ellipse3.Fill = Brushes.Red;
                    Grid.SetRow(ellipse3, 2);
                    Grid.SetColumn(ellipse3, 0);
                    contentWindow.Children.Add(ellipse3);
                }
                if (window.Client2Bool)
                {
                    var ellipse4 = GetGreenEllipse();
                    if (window.RightFront)
                        ellipse4.Fill = Brushes.Red;
                    Grid.SetRow(ellipse4, 0);
                    Grid.SetColumn(ellipse4, 2);
                    contentWindow.Children.Add(ellipse4);

                    var ellipse5 = GetGreenEllipse();
                    if (window.RightMid)
                        ellipse5.Fill = Brushes.Red;
                    Grid.SetRow(ellipse5, 1);
                    Grid.SetColumn(ellipse5, 2);
                    contentWindow.Children.Add(ellipse5);

                    var ellipse6 = GetGreenEllipse();
                    if (window.RightRear)
                        ellipse6.Fill = Brushes.Red;
```

```
                    Grid.SetRow(ellipse6, 2);
                    Grid.SetColumn(ellipse6, 2);
                    contentWindow.Children.Add(ellipse6);
                }
            }

            return contentWindow;
        }

        private Ellipse GetGreenEllipse()
        {
            Ellipse ellipse = new Ellipse
            {
                Width = 25,
                Height = 25,
                Fill = Brushes.Green
            };

            return ellipse;
        }
    }
}
```

Client

```
using Microsoft.Kinect;
using ServerData;
using System;
using System.Collections.Generic;
using System.Linq;
using System.Net;
using System.Net.Sockets;
using System.Text;
using System.Threading;
using System.Threading.Tasks;
using System.Windows.Media.Media3D;

namespace _002___Client
{
    class Client
    {
        public static string ip = "128.243.19.128";
        public static Socket master;
        public static string inputState = "end";
        public static string CLIENT_ID = "CLIENT2";

        public Client()
        {
            master   =   new   Socket(AddressFamily.InterNetwork,   SocketType.Stream,
ProtocolType.Tcp);

            IPEndPoint ipe = new IPEndPoint(IPAddress.Parse(ip), 4242);

            try
            {
                master.Connect(ipe);
            }
            catch
            {
                Console.WriteLine("COULD NOT CONNECT TO SERVER HOST!");
                Thread.Sleep(1000);
            }

            Thread thread = new Thread(DataIN);
            thread.Start();
        }

        static void DataIN()
        {
            byte[] buffer;
            int readBytes;

            for (; ; )
            {
                try
```

```
                {
                    buffer = new Byte[master.SendBufferSize];
                    readBytes = master.Receive(buffer);

                    if (readBytes > 0)
                    {
                        DataManager(new Packet(buffer));
                    }
                }
                catch (SocketException ex)
                {
                    Console.WriteLine("Disconnected form Server");
                    Environment.Exit(0);
                }
            }
        }

        static void DataManager(Packet p)
        {
            // MANAGE RECEIVED DATA

            switch (p.packetType)
            {
                case PacketType.InputCode:
                    Console.WriteLine("RECEIVED INPUT CODE: " + p.clientCode);
                    if (p.clientCode == "exit")
                        Environment.Exit(0);
                    inputState = p.clientCode;
                    break;
            }
        }

        public void SendReferenceData(double[] referenceData)
        {
            Packet   referenceDataPacket   =   new   Packet(PacketType.RegisterClient,
CLIENT_ID);
            referenceDataPacket.SetReferenceData(referenceData);

            SendPacket(referenceDataPacket);
        }

        public void SendInputCode(string inputCode)
        {
            Packet inputCodePacket = new Packet(PacketType.InputCode, CLIENT_ID);
            inputCodePacket.clientCode = inputCode;

            SendPacket(inputCodePacket);
        }

        Packet bodyDataPacket = null;
        public void AddBodyData(ulong id, Dictionary<JointType, Point3D> bodyDictIn,
List<ColorSpacePoint> csPointsIn, float orientation)
        {
            if (bodyDataPacket == null)
                this.bodyDataPacket = new Packet(PacketType.Transfer, CLIENT_ID);

            this.bodyDataPacket.personList.Add(new pPerson(id, csPointsIn, bodyDictIn,
orientation));
        }

        public void SendBodyData()
        {
            if (this.bodyDataPacket != null)
                SendPacket(this.bodyDataPacket);
            this.bodyDataPacket = null;
        }

        public void SendPacket(Packet packet)
        {
            master.Send(packet.ToBytes());
        }
    }
}
```

Main Window

```
using System;
using System.Collections.Generic;
using System.Linq;
using System.Text;
using System.Threading.Tasks;
using System.Windows;
using System.Windows.Controls;
using System.Windows.Data;
using System.Windows.Documents;
using System.Windows.Input;
using System.Windows.Media;
using System.Windows.Media.Imaging;
using System.Windows.Navigation;
using System.Windows.Shapes;
using Microsoft.Kinect;
using System.Windows.Media.Media3D;
using System.ComponentModel;

namespace _002___Client
{
    public partial class MainWindow : Window
    {
        Client clientHelper;

        KinectSensor kinect = null;
        MultiSourceFrameReader msfr = null;
        FrameDescription colorFrameDescription = null;
        IList<Body> bodies = null;
        List<ColorSpacePoint> csPointsToDraw = new List<ColorSpacePoint>();

        Canvas canvas;
        double canvasWidth, canvasHeight;
        double referenceFrameWidth, referenceFrameHeight, referenceFrameDepth;

        public MainWindow()
        {
            this.clientHelper = new Client();

            this.kinect = KinectSensor.GetDefault();
            this.msfr = this.kinect.OpenMultiSourceFrameReader(FrameSourceTypes.Body |
FrameSourceTypes.Depth);

            msfr.MultiSourceFrameArrived += msfr_MultiSourceFrameArrived;

            this.colorFrameDescription                                              =
this.kinect.ColorFrameSource.FrameDescription;

            this.referenceFrameHeight = colorFrameDescription.Height;
            this.referenceFrameWidth = colorFrameDescription.Width;
            this.referenceFrameDepth                                                =
this.kinect.DepthFrameSource.DepthMaxReliableDistance;

            kinect.Open();

            Loaded += MainWindow_Loaded;

            this.DataContext = this;

            InitializeComponent();
        }

        private void MainWindow_Loaded(object sender, RoutedEventArgs e)
        {
            this.canvas = bodyPointsCanvas;
            this.canvasWidth = canvas.Width;
            this.canvasHeight = canvas.Height;

            double[] referenceData = new double[10];
            referenceData[0] = referenceFrameDepth;
            referenceData[1] = referenceFrameHeight;
            referenceData[2] = referenceFrameWidth;
            referenceData[3] = canvasHeight;
            referenceData[4] = canvasWidth;

            this.clientHelper.SendReferenceData(referenceData);
```

```
        }

        string inputState;

        private        void        msfr_MultiSourceFrameArrived(object        sender,
MultiSourceFrameArrivedEventArgs e)
        {
            ///READ INPUT STATE FROM CLIENT
            inputState = Client.inputState;

            ///DECLARE FRAMES
            BodyFrame bodyFrame = null;
            DepthFrame depthFrame = null;

            csPointsToDraw.Clear();

            ///ACQUIRE AND VALIDATE FRAME
            MultiSourceFrame multiSourceFrame = e.FrameReference.AcquireFrame();

            if (multiSourceFrame == null)
            {
                return;
            }

            try
            {
                //depthFrame = multiSourceFrame.DepthFrameReference.AcquireFrame();

                //if (inputState == "d")
                //{
                //    var depthDesc = depthFrame.FrameDescription;
                //    ushort[] depthData = new ushort[depthDesc.LengthInPixels];
                //    depthFrame.CopyFrameDataToArray( depthData );
                //}


                bodyFrame = multiSourceFrame.BodyFrameReference.AcquireFrame();

                if ((bodyFrame == null))
                {
                    return;
                }

                ///PROCESS BODY DATA

                this.bodies = new Body[bodyFrame.BodyCount];

                ///REFRESH BODY DATA
                bodyFrame.GetAndRefreshBodyData(this.bodies);

                foreach (Body body in this.bodies)
                {
                    if (body != null)
                    {
                        if (body.IsTracked)
                        {
                            Dictionary<JointType,    Point3D>    tdPoints    =    new
Dictionary<JointType, Point3D>();
                            List<ColorSpacePoint>        csPoints        =        new
List<ColorSpacePoint>();

                            foreach (JointType type in body.Joints.Keys)
                            {
                                Joint joint = body.Joints[type];
                                Point3D   point   =   new   Point3D(joint.Position.X,
joint.Position.Y, joint.Position.Z);
                                ColorSpacePoint                 csp                 =
this.kinect.CoordinateMapper.MapCameraPointToColorSpace(joint.Position);

                                ///GET LIST OF JOINT POSITIONS
                                tdPoints.Add(type, point);

                                ///CANNOT BE SURE THERE WILL BE DATA IF "TRACKED" IS
USED
                                if (joint.TrackingState == TrackingState.Tracked)
                                {
                                    ///CALCULATE POSITION TO DRAW POINT
```

```
                                csPoints.Add(csp);
                                csPointsToDraw.Add(csp);
                            }
                        }

                        Vector4                    rotationJt                    =
body.JointOrientations[JointType.SpineMid].Orientation;
                        float x = rotationJt.X;
                        float y = rotationJt.Y;
                        float z = rotationJt.Z;
                        float w = rotationJt.W;

                        float yawY = (float) Math.Asin(2 * ((w * y) - (x * z)));
                        yawY = (float) ( yawY / Math.PI * 180 );
                        double degTol = 35;

                        if (yawY <= -degTol || yawY >= degTol)
                            yawY = 10000;

                        ///TRANSFER DATA TO SERVER
                        if (inputState == "transfer")
                            this.clientHelper.AddBodyData(       body.TrackingId,
tdPoints, csPoints, yawY );
                    }
                }
            }
        }
        finally
        {
            if (inputState == "transfer")
                this.clientHelper.SendBodyData();

            DrawPoints(csPointsToDraw);

            ///DISPOSE
            if (bodyFrame != null)
            {
                bodyFrame.Dispose();
            }

            if (depthFrame != null)
                depthFrame.Dispose();
        }
    }

    private void DrawPoints(List<ColorSpacePoint> bodyPoints)
    {
        canvas.Children.Clear();
        foreach (ColorSpacePoint point in bodyPoints)
        {
            ///NEW ELLIPSE REQUIRED FOR EACH CHILD ELEMENT ADDED
            Ellipse ellipse = new Ellipse
            {
                Width = 20,
                Height = 20,
                Fill = Brushes.Red
            };

            if (point.X > 0 && point.Y > 0)
            {
                ///CONVERT POSITION TO CANVAS
                Double     convX     =     this.canvasWidth     *     (point.X     /
this.referenceFrameWidth);
                Double     convY     =     this.canvasHeight     *     (point.Y     /
this.referenceFrameHeight);

                ///SET POSITION AND ADD TO CANVAS
                Canvas.SetLeft(ellipse, convX - (ellipse.Width / 2));
                Canvas.SetTop(ellipse, convY - (ellipse.Height / 2));

                canvas.Children.Add(ellipse);
            }
        }
    }

    private void MainWindow_Closing(object sender, CancelEventArgs e)
    {
```

```
            if (this.msfr != null)
            {
                // MultiSourceFrameReder is IDisposable
                this.msfr.Dispose();
                this.msfr = null;
            }

            if (this.kinect != null)
            {
                this.kinect.Close();
                this.kinect = null;
            }
        }
    }
}
```

Packet

```
using System;
using System.Collections.Generic;
using System.IO;
using System.Linq;
using System.Net;
using System.Runtime.Serialization.Formatters.Binary;
using System.Text;
using System.Threading.Tasks;

namespace ServerData
{
    [Serializable]
    public class Packet
    {
        public string clientID;
        public string clientCode;
        public double[] referenceFrameData;
        public List<pPerson> personList;
        public PacketType packetType;

        public Packet(PacketType type, string senderID)
        {
            this.referenceFrameData = new double[10];
            this.personList = new List<pPerson>();
            this.clientID = senderID;
            this.packetType = type;
        }

        public Packet(byte[] packetBytes)
        {
            using (MemoryStream mStream = new MemoryStream(packetBytes))
            {
                Packet p;
                try
                {
                    mStream.Position = 0;
                    BinaryFormatter bFormatter = new BinaryFormatter();
                    p = (Packet)bFormatter.Deserialize(mStream);
                }
                catch (Exception exc)
                {
                    Console.WriteLine("DESERIALIZATION    FAILED.    Reason:    "    +
exc.Message);
                    throw;
                }
                finally
                {
                    mStream.Close();
                }

                this.clientID = p.clientID;
                this.clientCode = p.clientCode;
                this.referenceFrameData = p.referenceFrameData;
                this.personList = p.personList;
                this.packetType = p.packetType;
            }
        }
```

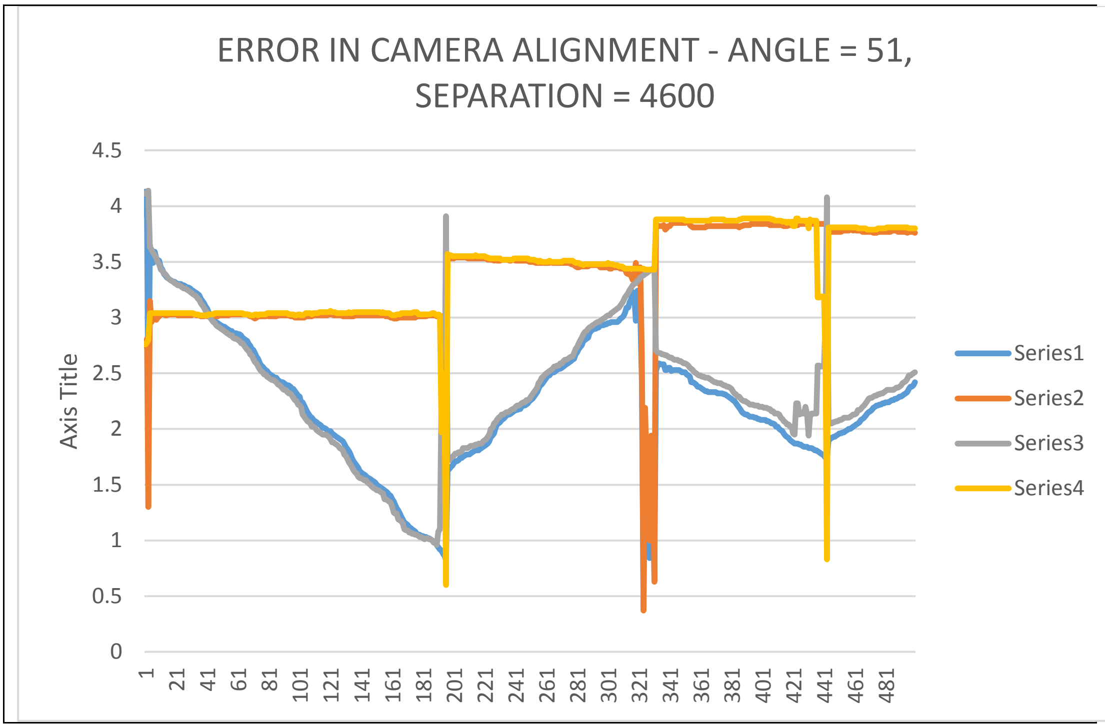
```
        public byte[] ToBytes()
        {
            using (MemoryStream mStream = new MemoryStream())
            {
                BinaryFormatter bFormatter = new BinaryFormatter();
                byte[] bytes;

                try
                {
                    bFormatter.Serialize(mStream, this);
                    bytes = mStream.ToArray();
                    mStream.Flush();
                }
                catch (Exception exc)
                {
                    Console.WriteLine("SERIALIZATION FAILED. Reason: " + exc.Message);
                    throw;
                }
                finally
                {
                    mStream.Close();
                }

                return bytes;
            }
        }

        public static string GetIPforAddress()
        {
            IPAddress[] ips = Dns.GetHostAddresses(Dns.GetHostName());

            foreach (IPAddress i in ips)
            {
                if (i.AddressFamily == System.Net.Sockets.AddressFamily.InterNetwork)
                    return i.ToString();
            }

            return "127.0.0.1";
        }

        public void SetReferenceData(double[] referenceData)
        {
            this.referenceFrameData = referenceData;
        }

        public void AddBodyData(pPerson person)
        {
            if (person != null)
                this.personList.Add(person);
            else return;
        }
    }

    public enum PacketType
    {
        RegisterClient,
        InputCode,
        Transfer
    }
}
```

pPerson

```
using Microsoft.Kinect;
using System;
using System.Collections.Generic;
using System.Linq;
using System.Text;
using System.Threading.Tasks;
using System.Windows.Media.Media3D;

namespace ServerData
{
    [Serializable]
```

```
    public class pPerson
    {
        private ulong ID;

        public List<ColorSpacePoint> csPoints;
        public Dictionary<JointType, Point3D> bodyPointsDict;
        public float orientation;

        public     pPerson(     ulong     id,     List<ColorSpacePoint>     csPointsIn,
Dictionary<JointType, Point3D> bodyPointsDictIn, float orientation )
        {
            this.ID = id;
            this.csPoints = csPointsIn;
            this.bodyPointsDict = bodyPointsDictIn;
            this.orientation = orientation;
        }
    }
}
```

C4 Camera Alignment



Appendix D – Responsive Study Results

D1 Transcripts

User Study 2 – Trial 1 – Transcript 1

P5 – ".. I could see where my space was, I could see what I was seeing. I didn't want to interrupt anyone else … when I stepped in to the room I would move to one side to make sure they had an available space. Whereas if I was in an exhibition I probably wouldn't do that … No, I'm at the front now holding my space so I can look at this for longer."

Researcher – "Is that because the content was mapped to you?"

P5 – "yes. I could move across and still see it clearly and make space for others. It was nice to be able to do that, but it was like I was more conscious of others in the space than I was about seeing what I was seeing."

P2 – "I think if someone has never seen anything like this before, then initially when you walk in you want to walk to the place where you can see the information *content already shown for another user* before it picks up that you are there, and then it appears double, and obviously you can see it. So I think it could take a little bit of time for people to realise that something else has appeared in relation to where they are stood, rather than just following where the information has come on the screen."

Researcher - "So if you were coming in perhaps second or third?"

P2 – "It would be more obvious because you can see that there's different … they're all across, saying the same *first page, or whatever* so you would think it's responding to a person looking at it. Whereas, if you first walk in you might think *oh look* that's where I need to go an read before anything's appeared yet for you."

P1 – "As someone who came late both times, I think you tend to think of it the other way around, I just came in and wanted to find a place where I could just see something without disturbing the others, and by the time I would find a place and look at it, the content would have moved, so it's a bit frustrating."

Researcher – "So in a similar point, you were coming in and trying to go to where some content already was? (P1 - YES), but then content would start moving and that would cause a problem?"

P1 – "Yes, I would adapt myself to both the content and the locations of people, because I know I am tall and I don't want to be disturbing anyone. And by the time I had found a good angle *to the screen* it had moved."

P3 – "The first time I came in there was a different bit of text from the PAGE 1, my sense coming in after a few people was I had to be reading around, I got that there was a bit of text that was coming to me based on my location, but then I found myself reading around and some bits were repeated and some were new. If I was looking at something, a piece of text to go with a piece of art, I would maybe find it a bit of an overload, a bit of a cognitive overload, that is perhaps taking away from what I am looking at. If I was in a museum I would look at a bit of text and I would let that sink in while I was looking at the art, whereas I wonder if there is some potential for overload. With being able to see everything else, I was wondering if this was relating to me or is that … do I need to read that kind of thing.”

P5 – “I can see how that in different museum scenarios, maybe not an art gallery, but maybe a historical display that goes through the ages and you’ve got that continual *boardwalk of text* that you can’t always see it, so if it’s moving with you and not disturbing, not overlaying the display, but is instead something that just moves with you, I think that would be really useful. Then you don’t have to keep searching *I’m standing here now* what’s this about, you don’t have to guess and try and pair the information together. If you’ve got quite a chaotic exhibit that’s quite long, then it would work in one way, but if you were overlaying something where you were meant to be quite mindful and stare at it for a while and let the information sink in, then I think it might be a bit too much.”

Researcher – “Especially with multiple people?”

P5 – “YES. You would see too much and be distracted by what others were doing and be more involved in what others were doing and like I said, I was more aware and moving around to make space for others. And while that’s a nice thing so everyone can see, I wasn’t really focussing on *here I am* this is what I’m doing, so I was more distracted.”

P7 – “It happened to me in the first exercise, it was difficult to find a gap. Most of the people were taller than me. There was a lot of information on the display, but there were a lot of people in front of the screen, so it was difficult to find a gap. When I did find a gap the screen *system* was broken. In the second exercise it was easier, I saw one person each side and I tried to fit in the middle and I realised the screen was following me. In the middle *join of the screens*, you have both screens fitting together but there is a problem. I decided to move one step to the left. It is a detail that is interesting, there was a problem with the screen so you had to find a better spot to be able to see.”

P1 – “Another thing, I think it is a visual design thing. When I first arrived the two bits of information were already on screen and I struggled to understand which came first because the page numbers did not stand out.”

Researcher – “That was trying to read someone else’s content?”

P1 – “I didn’t know that this is your content and not someone else, there’s no cue to tell you that these things are personalised”

P3 – “I agree, and adding from that, I can imagine something like this with different colours *or something like that* to indicate the number of people *ownership*. If there is a known colour then I know where I am supposed to look, some kind of cue that allows you to know where to look.”

P1 – “In some museums you are given stickers to show you have paid, so if the sticker matches something.”

P5 – “If it was on a reflective surface you would know it was following you and that you were not just interacting with a blank wall, because you can see you shadow or something like that to know that that content is following you. It would make it quite clear, especially if there are multiple users, it was quite easy, really easy for me to know it was following me as I was one of the first one’s in I could see it was following me. I watched the other users come in, but I can imagine the other users coming in when there’s already quite a lot of information already there, seeing that one has popped up exactly for you, without seeing how it's seeing you or how it's putting you on the screen would be difficult."

P7 – "I wasn't disturbed by the presence of others, but with a mirror or something I think it would be distracting."

P5 – "With crowding of the visual space, I think it would be hard to read on a reflective surface anyway, but then you would get distracted if you were with your friends and they started pulling faces *in the mirror* then you would probably not read anything. So I think there are many variables that would alter these things with multiple users."

P6 – "Maybe this is out of the focus, but maybe if you can use a gesture to tell the text to follow you, maybe that would give you the feedback to tell you that that's yours, rather than immediately following you."

P5 – "Maybe holding up your hand or something would trigger the information to pop-up and then you know that that is yours and it's going to follow you. That would be kind of like if you want the information or not when you're looking at a specific exhibit I guess."

P1 – "Those who arrived early, did you feel that the time you had to read the first bit, before getting the second bit was appropriate, or did you think you would want something to make it go faster or …"

P5 – "I think it was kind of on the slower side, but not ridiculously slow"

P2 – "These are just little things that can be changed, but the concept so far seems good. There's a lot of speculation though as we were only here for a maximum of 30 seconds before it stopped. I was just thinking, oh if I start waling this way is it going to come with me, but I didn't get a chance to test it."

P5 – "And how would it work when it collides with other users."

User Study 2 – Trial 1 – Transcript 2

Researcher – "Would anyone like to say what they think happen that time?"

P2 – "Something that happened this time, that didn't happen last time, was that a couple of us switched places, and I noticed that the screen *window* got a little bit smaller and moved across, but it was actually quite smooth. It was really obvious that, even though I was moving it was following me, so I didn't feel like it was confusing. The only thing I would say that was distracting, the screen to the left of me was flickering a little bit until *participant who had the screen* moved forward and it kind of stabilised."

P5 – "I think it was kind of nice when everyone was spread out and the space was there, that's when it was fine with us being a group of 7, but when everyone started to move around again it *the system* didn't like that. But I guess it worked well in creating space for each users in a way that you may not have done if you were looking at the same piece of text or screen. Because it was all paced out you were able to create that space for one another, and also be slightly guided by the fact it was mirroring you. You said *P2* that it flickered or got stronger, so you knew you were in enough space for it to just interact with you and not anybody else, and that kind of made me chose a spot and then we tried to move and broke it."

P2 – "I think that's a good point actually, that you can spread out while all reading the same thing. Some times in a museum there are some times where there are quite a few people reading something and I'll think, oh never mind, and just walk on to another thing because I don't want to get in other people's way but I also don't want to hang around waiting for ages. So you might just say, oh I'll leave that, but here you can …"

P4 – "I was quite conscious of other people around me, but it was nice that I could still see what was going on and be able to move back and let other people come in."

P1 – "Because I came very early I couldn't really gauge the difference. It almost feels like you could use this to manage flow of people, because once I'm done reading the second bit, I was wondering is there something else going to show, or should I just move. If there's a pointer or just a fade out, something telling you it is time to move on."

Researcher – "Did anyone particularly notice a change, or those who came in earlier, *several* people have mentioned they were able to find their own space. Did you particularly notice the relationship of other windows to other people? Did you feel there was anything happening there with what you could see?"

P1 – "I saw something when someone came past me, I saw them jump over me with the fading animation."

P7 – "I think I was very conscious about the presence of other people around me. Just looking at the screen I could identify what they were doing, like walking behind or trying to move in front of me. I have a conscious of their presence, but it's not interrupting my view."

P5 – "It made me really conscious, because I knew and could see they *windows* were interacting, so I didn't have to look around me to know where people were, I was very conscious to stick to my place rather than trying to overstep anybody else's view, so instead of get in their way, I'm just going to stay here where I've got a lot of space. You would need eyes in the back of your head to be able to do that in a normal exhibition situation. I think people aren't very conscious of that when they are in group settings."

P1 – "Being tall, I think in natural situations I wouldn't mind being behind and watching over someone, especially if it's crowded, if it's crowded it almost feels like you are stalking the person. The fact that you have the animation *interaction between windows* it feels like this is not something you can do."

P2 – "I don't know if this would work, but if you did attempt to stand further back would it attempt to do another screen *window* for that person."

Researcher – "Each person is receiving their own window, which is set according to who is closest to the screen. The windows are set to head height for comfortable reading."

P6 – "It is interesting, normally if someone is behind, they should have a higher *larger* sized text."

Researcher – "These are factors of the presentation, unfortunately there are a large number of variables for showing content. This configuration is attempting to be as simple as possible.

What has been noticed, is that everybody who is coming in is lining up at around 2m form the display."

P1 – "One thing that is really affecting it is the quality of the projectors. If you are too close it become uncomfortable. This distance is good for my personal eye sight. One thing about quality, I am aware it is a limitation for this trial. I wanted to move and chose the best angle, but you can only do this once you have settled. The quality of the display is not good enough to be able to read while moving."

P3 – "I would suspect this is the average distance that people would stand to displays as well, probably here, but also depending on the size of the space, but also putting on the social norm of a gallery space. You would stand close but you wouldn't stand too close."

P1 – "I think it is also the configuration of the room, because in a normal gallery, you would have corridors that are much smaller *narrower* than here. You would not necessarily be standing here, but you would be reading content while you are going to another place."

P2 – "I was about the fifth person to come in this time. I think I followed human behaviour and saw that everyone was standing here, so I'll just go there. I think I would have felt a bit weird if I'd just come in and stood right in the middle or the front."

P3 – "You want to find a gap in the line, we all subconsciously formed a line, because of the spacing we had all formed a line and could interact or find a space where we could interact without interrupting others. Oh there's a gap in the middle, I'll just go there, but I didn't go any closer. Maybe it's because I've got my glasses on."

P2 – "It was comfortable for me once I got there, you just tend to do that *follow other people*. But I think if the whole line had filled up and you let more people in they would naturally form another line or go in the gaps, but what that would do to the display I don't know. Because it's trying to follow every person, but someone stood here *near another window* might be able to read another one just as well, I don't know if they would need another window. I don't know what would happen if you' tried to get more than 7 people in."

P3 – "As you *P1* were saying, I think this would be good for management of flow, but wouldn't necessarily be good for management of a crowd. If you had a museum where you were following through, along their track route and they kind of allow groups to go in, some people will tend to stay longer on some bits. But if you don't have that and it's just a room where they had several corners where you could go anywhere but didn't have as much control, I think it would struggle to manage the crowd but it wouldn't struggle as much if it was like A to B, or you're transversing this transition point to the next and this is following you, then this is fine, everyone's going to give the right distance because they notice the interactions more, but if it was a crowd and everyone just moved forward to look at it, I think it would be a bit more difficult to get that fully representative of the people stood behind, people that are everywhere around you *and shown on the display* it might make it more confusing and more overloaded than anything."

Researcher – "So would you say this is a comfortable number of people, even though it is having trouble?"

[AGREEMENT FROM ALL PARTICIPANTS]

P2 – "Obviously it is a very large screen"

P5 – "For screen size and text size and what we're currently looking at, then yes. If the information was bigger or there was more to it, then maybe not. It depends what the design or delivery of content was. Where would the exhibit be or how would it relate to the content."

P3 – "I deliberately came over to this end just to see how it would pan out, but when everyone came in I wanted to test it a bit to see how far *it would track* but weirdly I think I moved only to about here *around 1 m away from the edge starting position* because I felt I was kind of blocking other people. I wonder if there's a mobility thing, where in and around the centre you have more mobility. Socially I would have felt strange walking across everyone or even waling behind."

P5 – "I was really conscious too, when I walked in front of you *P7* I even ducked, so I don't know why I did, I was just a bit like I'm going to sneak past. I wouldn't have done that if I was in a normal museum, but because I could see my content interrupting someone else *slight discomfort* but it's too late, it's done it … sorry, woops."

P1 – "I am thinking of other examples of when I have encountered other screens in museums and often it's because you have some content being delivered, but it's often hard to know how long the content is going to be delivered. It is often videos that are on short loops that are around 3 minutes or something. But if you think it's something that is going to be very engaging you might want to interact like this *sits down* but at the minute I am not sure if I want to do that *interact this way* there is no indication."

User Study 2 – Trial 1 – Transcript 3

Researcher – "You *P3* did mention it was lots of fun to play with, what were you guys up to?"

P3 – "I think it was mischievous fun rather than fun that was programmed in, I think it was figuring out that you could make other people's text disappear by sort of blatantly walking in front of them. I think that led on to a very good point about children, I think if you've got children in that space running around, or gaming the system to annoy other people, it adds an element of mischievous fun. But I probably wouldn't do it to strangers."

P7 – "The mechanics about the interaction, it is easy to control but it is easy to play with."

P2 – "I think that's more because it's a novel system, you can do that anyway *and just block someone*."

P5 – "Yeah, but because you're more aware of it."

P2 – "It's a novelty, because you can move it without touching it, you can just walk past it. I don't think adults would be doing that, I think it's more children. When you realise there's this screen with writing that's following them, I don't think they're going to sit down and read this in a socially acceptable manner."

P6 – "It would be interesting to let them pick what they would like to happen when they walk in front of another person, from *very disturbing to other* to *probably not disturbing others* to make it even more fun."

P3 – "It might make a really interesting social part, where when you walk past they all bind together and they will only unlock if you have a conversation about whatever's in front of them, so you end up having social interactions with people based on …"

P5 – "If it asked you a question and you had to answer a question based on …"

P2 – "I don't follow the whole unlocking thing, but I think that just that initial thing that if you walk in the periphery of someone else's screen, that they just join so that you're reading the same one. So if someone is standing behind you or just walking past and then if they were to walk the other way it just appears again. So you're not disturbing what other people are doing and you're free to move, but you're saving space, because more people are able to come and stand there and just read the text because it would recognise that you are all there stood in a group. But also if one of you moved you could follow them and tidy it up a bit."

P3 – "It would be nice to have colours *for each person* and you could mix the colours up when they join together."

P1 – "You feel like you want some more information about your content, especially if it is giving you important information. If you want to take down notes, or you are talking to someone in the group and you are busy, when you come back to it you have missed an important bit of information, how would you get back to that."

P5 – "That is a problem with museums at the minute, if they are showing *interactive* content, it's usually just a loop, it's not really that interactive, it's just press play or chose an option. If you want to move on or feel over crowded, you can start it again from where you were. It would be nice if you could manage the content, fast forward or rewind or skip to a bit you were really interested in."

P1 – "I know when visiting with friends, some people are either faster at reading or they just want to skip bits, so there is this whole group management thing you have to think about."

P5 – "I would say something like this would keep me in an exhibition longer because I'm the person who goes all the way through and says done, and the person I'm with wants to spend time reading things. Where I am ready to go and they are not ready, I don't pay attention as much, whereas something that was interactive might keep my attention more. I think it would help me to keep focus and move through something at a reasonable rate and engage with the content."

P2 – "In a museum or gallery context you can update the content really easily. Instead of laminated writing behind glass. Something like this can be amended as much as you like, digital text. It can be updated as much as you like, or adapted to the audience. You could have a child's version or an adults version."

P5 – "If it was showing a map or something, it could have recommendations or extra information, like tweets or something for social connectivity for museum visits. So you could see what other people were doing and enjoying. I would go for a specific exhibit or one or two thing, especially larger museums, so having something that could recommend routes or be updated in real time would be really nice."

P6 – "It could also be used to show your location in a very big museum. Always having access to a GPS orientated map so you can always have access to that information so you can easily get to another place. Follow the information instead of the information following you."

Researcher – "So people are touching very much on the content specifically, which, wasn't the key factor in what you just experienced. The content was a placeholder, to allow you to interact and spend some time at the display. There are a couple of people at this point have mentioned that it *the display or windows* could be used to lead. This is actually the next study that will be taking place in around 6 weeks time, which you are all welcome to come back and try. This is looking at how the display might influence your behaviour. Today's study was looking at how you would interact with the display, how others used the display and how content was shown and how this in turn might affect your behaviour.

What we are now looking at is how you personally might have used to space, ow you might have interacted with the display *windows* and how the display in turn may have affected you use of space. Several people have mentioned they used strategies i.e. I purposely went here and did this action or behaviour to interact with the display. So just for the last couple of minutes, if there's anything that comes to mind about,, your movement, other people's movement, what was shown, where the content was, not what it was, and how those factors came in to play."

P5 – "I quite liked how, you said it mapped to head high, so we were all in a relative scale. But as I am much shorter than most, I liked how it didn't make a massive discrepancy for me … like this one is clearly the short persons … It made it feel like it was identifiable as mine, it was at a comfortable reading height, but it meant my content wasn't so identifiable to others where my content was. I'm not sure if it was a nice thing or not a nice thing, but it was generic enough and personalised enough, so the balance was personalised enough for me. But like with the sitting down thing, it didn't come lower when you sat down, I guess you disappeared off the scale then so it just kept it at a standardised height."

P1 – "So in terms of where it was, I'm not sure if it's relevant to your study, but there is a sweet spot in the middle where the screens overlap and you cannot read. So at one point I was trying to avoid it."

P5 – "I think being aware of the boundary of things, when I became aware of the line in the middle, and something you said about being too close to edges, or where it gave me more flexibility to move or look, as soon as I became more aware of the boundaries, I was very aware of moving within them, or get stuck too close to the edge where it might not react as well."

P6 – "Did anyone try to move out *before it crashed*"

P1 – "I did try at some point, where I was saying, OK, I don't really have anything to read, so I will just move out."

P5 – "Yeah, I noticed them fading as people were stepping back and forwards."

P1 – "You were talking about the edges, and I have seen in many museums that people like to walk from the edges, because they feel like it's the place where they disrupt the flow the least, so you have to support people wanting to walk from the edges."

P5 – "I suppose if you have this kind of interactive content, the reason they watch from the edges is because there is a crowd in the middle. But if there was this management where we all found a space and as a group navigated the space to find a space *to view the display* because we could all see where people's viewpoints were, I think maybe that's like a social context that's quite interesting. If you are anxious about being in a crowd or being in the middle you are always going to stay on the edges, but if you can see quite a big gap or space, which when I entered last and everybody was in a line, there was quite a big gap, I guess because everyone was avoiding the layover point, but I went straight to the middle that time."

P7 – "That worked especially for you, like to spend more time than the average looking at something. That's what I would try and do, find a gap and spend the most time just looking at the window. I never tried to move so much, staying in the same place and focus on the thing."

P2 – "I didn't feel the need to actually move when I was stood there. If I was in a normal museum or looking at static content, I think I would have moved because the walls not going to start moving *no adaptation* so I can move, but also to read the flow of text, you've got to move around *go to the next piece* but because I knew that standing there it was going to do page 1 and page 2, I didn't feel the need to move. So when I was moving around it was purely to test it, I didn't feel like I'd actually need to. It was only because I was prompted to move around and test it, but I didn't feel the need to actually start walking around, I was actually quite happy to stand there."

P5 – "Yeah, it's quite strange, because it's interactive it could move with you, I could understanding it leading somebody but I couldn't understand that once you've found a comfortable space, because you've used to find a comfortable space, and then once you've done that it's fulfilled it's purpose and I'm going to stand here and read the rest of this content and then I'm going to move on to the next one and hopefully it's going to pick me up and I'm going to get the next *window* and I'm going to read the rest of the information."

P2 – "Obviously we just had that *written text* to look at, but if you had a big model or something with lots of bits of information, different mannequins or something, more to look at."

P5 – "What if the pages changed when you moved."

P2 – "Then you would have reason to move around, but the text would still follow you. But because we were purely doing that, just looking at the text, I didn't feel the need to be walking around."

P6 – "So basically it needs to be more like a Pokemon Go."

P1 – "There's one thing interesting, apart from the very first time, I had expectations of what was going to happen, but in a museum context a lot, or the majority of people will not have experience of this, it will be their first *and only* time with the system. So, it works because finding the gap, there is also a gap between people, but people have no awareness of the system, they won't be looking for the gap by looking on the screen."

P5 – "I suppose in then goes to say how it would fit in the context of the experience. I guess the reason we discussed content is because then you can see how it would fit in, but it is hard to see how it would fit in if it was just in a room where there was no explanation of what, or there's not an introduction of the technology. So if, as you say, it was showing a map or something, you would be introduced to the technology before you ever actually get to use it. So it is where it falls in to play as well, I think it would have a big influence on how people interacted with it. Moving from A to B would be a very interesting thing, and where the information is going to be given to the user about, or whether it's all about discoverability. I think we all enjoyed discovering what happened and that added to the enjoyment of the experience but if it was actual information in an actual exhibit, would that be irritating, we just don't know."

Researcher – "This is where some of the interesting questions start creeping in. So, if you were left to your own devices, are you just going to cause trouble for each other and just try and make it as fun as possible. Or if this system then had some awareness of those behaviours and sought to stop or mitigate these behaviours in some way, how would that then change the experience? So if there was an awareness that people were interacting a way that wasn't working for one or both of them, and it *the system* then moves you away, opening up more space for instance …"

P1 – "What do you mean by moving you away because you always have the option of eves-dropping on someone's content and you don't really need to move."

P5 – "Yeah, I suppose if you've got like a social context and somebody might be standing uncomfortably close in your personal space, and that happens at museums and places with large groups of people, they've always got the option to read over your shoulder, and it might actually encourage it more if you move their content away, because they could just say *screw it* I'll just read hers an get really close."

P1 – "This may especially happen if you are a fast reader and you want to skip things. So I might think what is this persons content, Ooohh, that's interesting how can I find page 3. Why am I surfing on 2."

P5 – "Yeah, I think there's that, almost that personality of the museum goer. Each person has to, or is going to have their own way of interacting with it, and that is exactly how I would be because I have very little attention, but yeah I think there might be other people who might get annoyed by that behaviour. I think the best way, as we discussed, would be to merge content if you get too close because if you make it bigger, they're likely to separate out instead of staying close to the other person. If you make it take up two spaces once it's within those bounds, then it occupies more space and gives you more freedom, but then you might end up with loads of people all merged together and you're just in the same place where you started."

P1 – "I think the conditions we had here required a lot of attention, but this display requires a lot of attention, so this phenomenon, you can move your head around and move it back and you cannot remember which display is yours. Or you can be looking at your display and not really reading or not noticing that the page has changed, but that's also because of the font, the layout and so on."

P5 – "I think it's also the novelty because we're looking at each other's screens and thinking this is interesting, but maybe because of that novelty fact we are not necessarily looking at our screens *windows* because it's placeholder content and we're aware of that. If it was something that we had to physically read and we had to answer questions on that, I think I would have been more aware of that and stuck in my place more."

P7 – "I think it's going to be totally constrained to the space or the shape of the room, because if it's just an alley that you need to walk around you are going to have just close interactions with other people, and I think it's completely different if you have a big space and just if you come in to a room you have the opportunity to look at this type of display, or move around the information, probably just look at the first page and then pop to the third page."

P2 – "Just to answer what you were saying, how would you feel if you were messing around with it, I would think if I was messing around with a mate or something and I'm going to try and make the content disappear or something and it did disappear, I would think oh, this is a bit of a bad design. In a museum or gallery you would imagine they had thought about it, whereas If I tried to walk past and my text box just stopped or it merged with it, or like you said it started moving me to the left instead, so that it made more room, I think I would think oh, that's clever, this is more sophisticated. I don't think I would be annoyed and think *I'm not going to stand there* because I don't think most people are like that, I'd be like oh this works quite well. If it just faded when you walked past someone and then reappeared when you were past them I think that would be good, because you do need to think about these things."

User Study 2 – Trial 2 – Transcript 1

Researcher – "Would anybody like to say what they think happened during that study?"

P11 – "It detects where you are and the text is linked to your position, so if you move the message moves along with you. So the way I would move I would try and get a comfortable space for myself so there was enough space for the pop-ups to show for other people with them having their own comfortable space."

P8 – "What happened to me was that two of the new visitors came from my back, so I couldn't see them from the first place, then I moved a bit on the side so they would have space to have and read their own."

P13 – "I think I tried to magnify it I think by going closer because I was expecting that, but it didn't. I was going backwards and forwards, but it didn't. Then I just tested the limits, because it blurred itself I think if you go too far to the right."

P9 – "I was just hanging out in the back and saw the message."

Researcher – "I noticed that you went in at the very end, did you try and … , did yo notice anything about the windows that were already shown and the other people, or did you tend to stand back and read what was already there."

P9 – "I tend to stand back, I read what was already there, it was moving and the windows were moving. I was trying to see."

Researcher – “I think you have already mentioned *P11* when you walked in the window would follow you, so the people who went in earlier did you also notice that [ALL CONFIRM YES]. Was there anything about how other people were moving around and what then might have happened on the display that you might have noticed?”

P11 – “I guess we didn’t go close enough, but I guess if we were really close, we didn’t test if it would overlap or anything, but I guess the situation didn’t present itself or anything.”

P14 – “I noticed that when I was in the back of somebody else, that my window is hiding. So I can’t’ really see.”

Researcher – “So did that then affect what you did or your behaviour?”

P14 – “So then I kind of moved out from behind them to see my message.”

Researcher – “Did anybody else see anything else like that at all? You were quite happy where you were and your content was in front of you?”

P12 – “When I walked in I could see one of the squares with the text in, and I could see that if I stand behind that person and give them comfortable distance so they don’t think I’m standing right behind them, then I could focus on that and see that particular one.”

Researcher – “So were you reading what may have been someone else’s window, that was in front of them and not in front of you?”

P12 – “Potentially yes.”

P8 - “Can I just say something, I really liked how it felt like each window was your own personalised window and it followed you everywhere you go. I just really liked that.”

P11 – “I didn’t expect there to be so many duplicates. There was already one box and then another, so I usually read everything on the screen, so I didn’t expect to read a repetition of everything I have just read.”

P13 – “Maybe the change of pages, like the first page changed quickly and then it just sat on the second page. I think we were sitting on the second page for most of the …”

Researcher – “So you’ve already picked up on that. There is not a lot of content, it is designed to be a quick trial. Once you go in you do not have to leave, but it is not designed to be particularly fast or long.”

P8 – “So when we finish reading we go out?”

Researcher – “You can if you like, if you want to keep reading. If you want to think of this as a museum or gallery entrance space, where you can walk in, read some information about the museum or gallery, and that might direct you to another part of the gallery or direct you to some information and you would then naturally tend to …”

P8 – “Should we pretend that the other windows are saying something different?”

Researcher – “No, they are personalised to each individual. Each person will get a window and it will have the same content.”

P13 – “I imagine it is like different painting, so each would receive different information based on that painting.”

Researcher – “At the same time, the comment you made *P11* you would read everything on the display, is also very interesting. If there were several *seven* pieces of content on the display it would be very interesting to see you reading all of them. So comments like that, about content being boring are still interesting.”

P8 – “Yeah, I started to do the same, I started seeing what others had, I wasn’t sure if it was similar to mine. So I started to check every window, but when I checked every window I understood it was the same so I didn’t bother to read it afterwards.”

P12 – “I think you would move around less, because you could see from where you were standing it was the same. But if you could see they were different you might move around more to see what they were reading.”

Researcher – “So very quickly, you *P11* wanted to read all of the content on all of the windows, do you think that affected where you stood? Did you make a decision about anything like that?”

P11 – “Erm, no. Because I think I was second, so as soon as I saw, I first read *P12* so I could already see there was duplication, so I sort of got it right away that the box was mine, everyone got their own box, so I was just sort of moving, checking if it was really following me and checking to make space for the other people to come in.”

User Study 2 – Trial 2 – Transcript 2

Researcher – “Same again, would anybody like to say what happened that time?”

P9 – “So we went in first this time and I saw her *P10* screen come up, and like so she moved to the side, and I was standing beside her and I moved close to her.”

P10 – “And then the screen collapsed.”

P9 – “Yeah, and then the screen merged in to one. We tried to see what would happen.”

P13 – “It happened the same with *P8*, when they were next to me the screens collapsed and there was only one.”

P8 – “There was quite a problem with my screen, because it was glitching *P9 AGREES* and then this happened when they were merged, but eventually I had mine.”

P13 – “I think I noticed the difference between where they were triggered because yours was, the sensors were more in front than mine, I could go backwards and still receive mine. But for other people, they had to get a lot close to the screen to get the display.”

Researcher – “So how did it feel to have one screen instead of one each, I think each of you has now mentioned …”

P12 – “you are more aware of the people around you this time [AGREEMENT], so I think you were watching where you were standing in relation to other people to make sure they could see as well, when you realise that you don’t have your own individual screen *window*.”

P11 – “Personally for me I didn’t get close with the other people, so I still felt like I had my own screen *window* so mine didn’t merge, so I thought as long as you have your own space, you can read and then get out.”

P13 – “I think the merge makes sense, because couples who want to watch together on one screen, so if two people are very close together I think you can assume that they want to watch together, so it makes sense to have one screen, maybe a bit bigger.”

P11 – “I think for exhibits it’s normal to be this close, not your acquaintance, people you may not know, I think it’s normal. People you don’t know and it merged, I would be quite annoyed if mine just merged with someone else’s.”

P8 – “I also noticed that everyone was aware if they had someone on their back. So I could see that everyone did [TURNING HEAD] to see if there was anyone else, so that is I think thoughtful.”

Researcher – “So I think *P14* agreed with *P11* comment, which was ‘you had your own screen and you stayed in the space to keep your own screen’, was that an active decision?”

P11 – “Yeah, I think it is because each individual has the affordance to get your own screen, so just to be thoughtful you would limit the space you would use. You go in, you have your own screen, you read what you have and you get out so you can be thoughtful and more people can get in.”

P14 – “I think I experience the same as the one before, so I felt it was quite the same, so I didn’t think if the screen was merging together, I think it was hiding, so I can’t see mine anymore because it was behind somebody. I think it’s because we were told we each have our own screen, it’s not about social interaction between the screens.”

Researcher – “Do you think that changed your behaviour, you feel like you know how the system works so did that affect what you did?”

P14 – “Yeah, so I tried not to be beside of somebody, keep my own space, be separate.”

Researcher – “Did anyone have anything else, any more comments? [NO]. So in terms of how you entered the space this time, you entered perpendicular this time, instead of parallel, do you think that changed how you maybe *P9 & P10, you came in earlier this time* and the people who came in later, do you think that changed how you then approached the screen, or of the people who were already there, or of the layout of the screen?”

P11 – “Not really.”

P8 – “For me, yes.”

P13 – “For me, yes. Because I saw where they were, so usually I tend to go in a queue manner towards the edge, so I just went to the left side of the screen.”

P8 – “So for me the first time I think I was the third person to come I, so I went to stand at the leftist point I could stand. This time I came in straight ahead, so I just went straight ahead to a place where I could try to find some space, because I was the previous person before the last. So I just went to find some space, the nearest to me.”

Researcher – "So you just went to the nearest place where you could get to use the display. Did you notice anything about where people were already standing, and do you think that would have influenced your behaviour at all?"

P12 – "I went in last, so it was a case of everyone was quite evenly spread out, or it appeared that way, so I thought, where is the best place to get the best possible view."

Researcher – "Was everybody already standing in a line at that point?"

P12 – "Not really in a line, but no one was really bunched together on one side, it seemed like all of the screen, all of the people were making use of the whole space available."

User Study 2 – Trial 2 – Transcript 3

Researcher – "Would anyone like to say what they think happened?"

P14 – "So this time I think they recognised, I think it's clear that, who's behind and who's in front, so, I think if it was a real setting, so if I have to walk across in front of someone else, I think I would have to ask permission to go in front, because I have to hide the persons content that's projected, so that makes a kind of social pressure."

Researcher – "I think quite a lot of people were agreeing?"

[SEVERAL YES RESPONSES]

P9 – "So you had to like, really interact with the person next to you, I had to *have sex with them a little bit* for my screen to pop-up. At first it's faded, and I think he noticed, so I think he made space for it a little bit."

P12 – "I think if you moved aside behind the back of someone, you saw that your screen sort of went round the back of the persons screen."

Researcher – "So in particular, I think *P14* was walking in front and you noticed that you were causing a lot of te screens to change. Was that a decision you made and you mentioned there was a social pressure with that. Did that then change how you might behave, you mentioned you might ask permission, but did that then change your behaviour, your movement behaviour?"

P14 – "So you mean, compared to the previous one?"

Researcher – "Yes, well immediately what you are thinking about, if I feel this social pressure …"

P14 – "I think I tend to check if there is anybody behind me, next to me, so therefore I think I have to think one more for where to go, whether to just go back or to move in front of another person, so I have to think again."

Researcher – "So in that study, I noticed that you walked in front of several people, what was your reasoning for walking in front of them?"

P14 – "So first I wanted to check if my content actually hides theirs, so that was one thing. And, because it detects my position, so how far or close to the wall, so if it's zooming in or zooming out, as it is fading in and out."

Researcher – "So almost playing with it and testing the function of the system. So you mentioned there was this social interaction between other people and this social pressure?"

P14 – "Yeah, so I had to ask her *P8* can I go in front of you, because my content will hide hers."

Researcher – "So you were more curious to find out if you r content would hide someone else, than to go behind and hide yours. You already knew it would disappear I guess, so you wanted to see if it would work the other way around? [p14 - YES]. Did anybody else kind of do a similar kind of thing, were they playing with the screens?"

P13 – "Yes I did. I noticed hers was disappearing, so I had to move to the edge, but that kind of shifted my screen, because at the edge it just changes configuration I think, so it just burst. Then I noticed if I go backwards, mine, I think the sensors were picking up other people so mine just went to the background I think, so I had to go a little bit closer to the screen to have the full window"

P11 – "I think it's really dependant on what … let's say it's a museum right, let's say it's a painting. Typically people would move around because the text is all over the painting, you have to move around to read everything, but if all the text is just in that window and it's going to refresh as you stand there. People shouldn't really move around because they should just get a position if they want to read their content you just read it from where you are. One of your questions was like, the order of people going in, I think the social convention should be, you chose a spot and then the next people should choose their spot, they shouldn't really be moving around because all the content is going to be in front of you. So like, the adapt eliminates the need for merging and excuse me."

P8 – "Now we knew we are playing around, even if she didn't ask me if it was ok to move around, if it was a real situation and I was in a gallery and somebody did pass through me and my screen would disappear I would be a little *pissed off*, it would be annoying."

P14 – "Also, all the contents was the same, but if we all have individual content on the screen and mine hides behind another person's, then it's real *annoying*."

P11 – "You need to consider is there a need to move around, because typically people need to move around to read the content, but if you provide all the content on one window then it eliminates the need to move around."

P8 – "I think this is a real important factor, so if you identify from the beginning that there is no need to move around, then it's … "

Researcher – "Apart form if you are playing with the system, or something like that? [GENERAL AGREEMENT]. Another point was, you *P13* mentioned you were at the edge of the display I think, and someone was coming too close and it was making your content disappear, so you were moving closer to make sure you got the content [P13 AGREES]. Did anyone else do anything like that, move closer to make sure that they would get content? [GENERAL AGREEMENT]"

P12 – "As soon as you went to the back it started to disappear."

Researcher – "So there are combinations of blocking people on purpose but also fighting back to get your content back? [GENERAL AGREEMENT]. So, there was a final point, *P8* that if someone walked in front of you and blocked your content you would be upset, but would you be more annoyed because the content had gone or because they had walked in front of you?"

P8 – "I think I would be annoyed because they walked in front of me and the consequence was that the content disappeared, if they just walked in front of me, because this sometimes happens in museums and galleries [GENERAL AGREEMENT], because if this was a painting I could just still see the painting if they did that. But yeah, if the content disappeared it would make me feel annoyed, so I think it's a consequence of that."

Researcher - "So did you particularly feel that you had ownership of your window?"

P8 – "Eh, yeah … As I said in the beginning, it feels really good for me personally to feel that you have your own window. So, sometimes, at some points our windows had merged, so I thought, ok, I have to look at hers, but because it was hers that took in to mine, I thought mine is gone."

P11 – "I think it's more towards respecting other people's space, which includes the window."

P13 – "Or property, because it's their window."

P11 – "I wouldn't consider the window a property, because of how the system, I would consider you were invading my space which disrupts my window."

Researcher – "So there's almost a corridor, or something like that?"

P11 – "I wouldn't call it a corridor, but sort of like a sphere around me [P14 – Like your space], yeah, like my space and because if you know how the system works you wouldn't intentionally disrupt another persons window."

P8 – "So what I did by mistake, when I walked out, I think I didn't it the second time around, I think I was aware of it now so I was more careful. So when we would go out on our way out we don't actually remember that other people are still there, so on our way out we might interrupt people without wanting to interrupt. So if we want to not interrupt we have to go on the back, so that the sensor doesn't catch us and then go …"

P13 – "Maybe the sensor, when you turn your back away it shuts down the window, if that is possible, just using the camera's I guess. That would be nice."

P11 – "So I think that in a way, the most effective would be that people need to stand in a line with their own space to see, and when they move around they might disrupt other people's windows."

P13 – "Or just all enter at the same time in the same pace, not in a queue like now so you don't interrupt others. If we enter the space and we just occupy positions from left to right, which normal people do, that last person is going to disrupt everyone else as the go to the right position. So either just that, or occupying from the farthest point of the screen which allows the last person to not disrupt the others."

P11 – "There needs to be a system in place, because I think the social convention is, if we enter in a queue, I wouldn't take the nearest space to me, I would see what empty space is available and I take the space I like most from the available space. It doesn't have to be the nearest, it doesn't have to be the closest."

P13 – "the furthest one, there needs to be a social convention to take the furthest available as you enter. [GENERAL AGREEMENT]."

Researcher – "Do you think the number of people and the knowledge of the size of the screen is affecting that statement potentially?"

P13 – "Yeah, because we are already used to it after going through three trials we kind of know how it reacts."

Researcher – "I think the screen is actually full because there are seven people. You are all able to have a screen but you have to find a space to be able to do that ... You *P11* mentioned that you had your personal space and that there was content on the window that you felt was yours, so this might not be a question but an interesting point for the next trial. How does that feeling of personal space and what is on the screen, how does that influence your decision making, or your behaviour, or your interactions with other people?"

P12 – "One thing that I have noticed, if I was the last person in, the person that came in at the same time as me or just before me, if they have finished reading, you think perhaps maybe I should have finished reading or perhaps I should move away and I think that influenced me."

Researcher – "If everyone's doing it I'm going to leave as well? [P12 - Yeah]. Did anybody look over their shoulder as much this time. In the first two studies quite a few people mentioned they would look over their shoulder to see where everyone was, do you think you did as much of that this time?"

P13 – "I didn't as I was on the edge, so, I didn't feel there was going to be anyone."

P11 – "I think you would look over your shoulder if you were the later ones coming in, but if you were one of the earlier ones coming in you wouldn't have to, because if they stood behind you that's their fault."

P13 – "Because you expect them to realise your position, to adapt to your position, so you don't expect that if you are one of the first people."

Researcher – "I noticed in the first study, that when you don't have the blending, or the animation that goes behind, several people said that you could see them *windows* interacting, and you might look behind to see why or who was there. Bu this time the animation, I wonder if you don't need to look as much, you have a different awareness of other people in the space?"

[GENERAL AGREEMENT]

User Study 2 – Trial 2 – Transcript 4

Researcher – "Would anyone like to say what they think happened?"

P11 – "That last one seemed a bit buggy to me, because like, erm, I think *P8* was shifting next to me, also mine slightly went out of focus. I was still, I was very still and like I sort of my guess was that if it sensed you were slightly moving it went out of focus and if you were still it will come back in focus, but like, I was still and mine still went out of focus. Maybe because of *P8* and Kinect tracking or something like that, but it still seemed a bit buggy to me for that last particular one."

P8 – "I felt the same, because this happened to both people on my right and my left. So first of all mine couldn't focus, so I had to try and go very close to the screen and a bit more back, but then when I found the spot that I would be still and the window was ok, I noticed that the two other people who were next to me were trying to find their window again, so, I don't know what happened."

P13 – "It felt a lot more bunched together this time I think."

P8 – "But we weren't so close, it was a bit weird to me, especially as we weren't so close with you I think *P11*."

P11 – "My guess would be the text, the most recent person who came in and it provides prominence on that window possibly."

P13 – "Or the sensitivity is decreased so … for the tracking in that case, every small interaction would shift I think. I noticed that *P12* was gone for a long time I think at the edge, so, and all the others were just …"

P12 – "so I tried to move as close to the screen as I could get, before anything happens before it disappears and it obviously wasn't picking me up."

Researcher – "There are some *blackout* zones where it doesn't pick you up, it just isn't tracking. How did you respond to that?"

P12 – "I was like, aww, my screen, I felt like I had lost something. So I thought, I'll move back and try and get back in the middle to see if it reappears, which it did eventually."

Researcher – "Had you read much of the content at that point?"

P12 – "I had read it all, because what I tended to do was, once we got to know how it was going to work, was to read everything, and then once you've read everything have a play with it and see if I'm just going to move around and also see what other people were doing as well."

Researcher – "Did everybody read their own content window this time and have you been doing that for that last few trials? [GENERAL AGREEMENT]. So you would wait for the page to change to the next page?"

P13 – "Except once at the beginning to read it if was the same, in a previous test, but then I stopped."

Researcher – "So, you *P11* mentioned it seemed buggy, quite glitch, but you *P13* felt that you were more bunched up this time?"

P13 – "Yes I did at least, at certain points I just walked around where all the people were, so it seemed that all the people were closer to each other, and in a straight line, people weren't going back and forwards as much, it seemed that people were more in a straight line."

P11 – "For me I don't think there was any back and forward, distance wasn't really considered in this system, was it. If you go closer it still looks the same."

P13 – "It doesn't zoom."

P8 – "For me it was different, it stabilised when I went in to the front. Otherwise if I was in the back it wouldn't even appear."

P13 – "It wasn't tracking you I think, so it would not track your presence. So, the screen size remains the same even if you are forwards or backwards. The writing doesn't zoom in, if you get closer."

P8 – "No, it was different for me. It was small in the beginning, and when I went really in front of it, it went really big."

P13 – "Oh, you had the small window right."

P11 – "The out of focus window."

P13 – "Yeah , it was out of focus because it would track another person, so you would have to come closer …"

P11 – "I thought it was because you were moving and then it went out of focus, but I'm not sure."

Researcher – "So it's actually when you overlap another, across the width of the screen, so when you become too close, your personal space bubble, the person who is nearest will receive content and the person who is behind, they will be animated behind. So I was curious to see what responses might be, the strategy was to move closer [GENERAL UNDERSTANDING]. Did you then notice this affected the person next to you?"

P11 – "Yes, so when I did that, it annoyed, not annoyed, caused a problem to both persons next to me. First to the person on my left and then to the person on my right, so even we weren't very close, especially with you *P11*, I don't know why this happened."

Researcher – "So who were those two people? [P8 – *P9 & P11*]. So how did you *P9 & P11* respond to that?"

P9 – "I kind of, I think I kind of move forward and backwards, yeah, I think when I moved backward and when I get in that space, it kind of comes up again."

Researcher – "So you moved forwards to make it become solid?"

P9 – "Yeah, I did both, but it became solid when I moved backwards as well, because I have enough space."

Researcher – "Do you feel you moved away from where *P8* was standing, or away from where her window was, or just to the side?"

P9 – "I moved like, to the back I think, I don't really remember. I think I did move away from her a little bit, yeah."

P13 – "I think this time it was more about finding a balance, between the position with the windows and the other people, so we needed to find a spot where everything was right you and the other people around you. So the whole interaction was balancing …"

P9 – "Yeah, I didn't try to fight to go in front, I would go back and see what works best for me and people around."

Researcher – "Did you come in to the space before or after? [P9 - BEFORE]. But you were happy to try and find a spot. Were you *P8*, I think you were more towards the middle on the right hand side?"

P8 – "I was on the right hand side, but because I went in last I found a spot that was clear, so this is why I am telling you it was weird, because I specifically found a spot that could be my window, and I couldn't ge tit stabilised, so this is why I was moving back and forth, and back and forth, and this is why I was trying to do the same, I was seeing you *P9* going around the back, and once I saw this it was ok and it was stabilised for all of us I think."

Researcher – "So when everybody was there, I think this was a recurring, the middle of the screen always seems to be empty for the last person. Does anybody have a reason why they wouldn't go to the middle?"

P11 – "Because it's two screens, like you know when you put two screens together and there a join in the middle."

[GENERAL AGREEMENT]

Researcher – "So it's because of that in the middle of the screen, and everyone has seen that and you don't want it in your screen. Does anyone have anything else they would like to add … So we've talked about screens merging, or the layout of content on the screen, or what you might have done differently where you have grouped or stood together?"

P11 – "I would think for the last one, with the distance based prominence for the last one and the focussing, it's, I wouldn't call it necessarily fair, let's say I was first, but because someone was near me I would have to move closer, it seems a bit, in a social convention it might seem a bit challenging as well. Like, oh no I'm moving forward because I know I want to see mine, it might be a bit … it seems like a potential source of conflict, depending on how passionate the viewers are."

P13 – "That's one of the most interesting things I think, the matter of possession of the window, because this is my window, so people might like to share it or not of course, and that's really interesting about the interaction or the social interactions."

P11 – "So when *P8* moved and she disrupted my window, but I didn't really move, so I was just wondering why it was out, I didn't take a step at all. Some time it would come back on focus, so I was just wondering why. But if it's really based on distance, then people would have to step forwards to get their focus back."

P13 – "So it seems like a competition almost."

P11 – "Yeah, it seems like a competition."

Researcher – "So do you think there's anything the system could do to help with those situations?"

P8 – "No, I think there something like I said before *P13*, like having a label at the beginning of the room to say, please take your step on the rightest corner of the room, I think this would solve it."

P11 – "I think it could have a maximum number of windows."

P13 – "Numbers on the floor or something. [*P8* AGREES]"

P11 – “Slots on the floor. Like a parking lot or something.”

P12 – “Footprints. [*P8* AGREES]”

Researchers – “A minor problem with where this *conversation* is not going, is that this is how museums and galleries already work. You have pre-defined interaction points, which are separated from everyone else. The potential here is that you could have a more elastic system, something that stretches and works with the people that are already there, it becomes more dynamic and interesting. So for instance, when people come too close to each other, based on my definition of personal space, you notice the window becomes animated, but the problem with the animation is that it then becomes very difficult to read, it goes out of focus. So in the sense of this is how the system is, is there anything you would like to see, such as an icon or animation, or additional information that this is about to happen. So you can understand there is someone behind you when the window goes behind, is there more information that this display could show?”

P8 – “I think it would take too much time to do that.”

P11 – “I think it’s possible, because if you can track the content of each window and people are reading roughly at the same content, you probably could take how long they take on each window and average it. You could merge the window because people are reading the same information. But you have to know where the two windows are, like what information the two windows are showing.”

Researcher – “What I was kind of getting at there a little bit, was where the animation begins, you could put a red line up, to say maybe stop, or perhaps an arrow to indicate moving the other way. Would something like that be helpful?”

P12 – “I suppose if you’re in the zone and you’re reading and you don’t notice where people, perhaps like a red box around to say that someone is in close proximity.”

P13 – “Or just say, if you are out of focus then you should just move one step to your right or to your left.”

P11 – “I think that my issue with, it might slightly overload what’s on the screen. As a display I think that in a real setting you would consider the aesthetic of it, so that for people it’s nice to look at or nice to read at. So let’s say there’s lots of windows, or lots of proximity errors, it sounds like some error message screen.”

Researcher – “So for instance, when another window animated behind, I guess that was in the edges of your peripheral vision. Do you think that maybe helped you to understand what other people were doing in the space? [AGREEMENT]. Is it helpful to know that there are other people around you, is it more distracting, is it less distracting than the first trial where that didn’t happen, where the windows would disappear if they came too close?”

P8 – “It depends if you are thoughtful of the people around you, so if you don’t care it doesn’t matter to you, but either way, if you are going to look like this [LOOKING OVER SHOULDER] and you have information on your screen, I think it’s helpful.”

Researcher – “Do you think you would change where you stood at the display based on your particular behaviour, you said if you were selfish you just wouldn’t care about anybody else.”

P8 – "Yeah, I think we all did that during all four phases, I think we all were very careful about where other people stood, and I think we all tried to help them out somehow."

Researcher – "So you feel you would move away from it if you saw a problem, you would move away from that problem, if you saw someone struggling you would move away, it wouldn't be up to them."

P12 – "I think if it was people that you knew you would act differently than if it was people that you had never met before. [GENERAL AGREEMENT]"

Researcher – "So this was one of the point with *P8 & P11 * P13* as they knew each other previously, some of your interactions were quite interesting, you would steal someone's screen and then you would steal it back."

P13 – "I think it's a matter of playing as well, because if you're with friends I would be just comfortable to just steal the screen, and just out of curiosity, but I don't think I would do that with a stranger I think."

Researcher – "So for the other side of the room *P9 & P10 & P12* did you feel that not knowing the people maybe affected your behaviour, *P9 & P10* I think you both know each other?"

P9 – "Yeah, it does."

Researcher – "Did that maybe affect how you chose to approach the display, or where you chose to stand?"

P9 – "Yeah, I chose to stand next to her. She went in first and I went in second, and I chose to stand next to her."

P10 – "Yeah, I chose to stand on the right so I can give room to other people."

P9 – "When I went in second, if I didn't know her I would probably go to the far left side."

Researcher – "So if there was only one other person you would go as far away from them as possible. Does anybody else think they would maybe do something similar?"

P11 – "Yeah, I think if you really don't know the person, you're getting as much space to yourself, but also giving as much space to them as well."

Researcher – "So there is quite a clear line down the middle of the display, do you think you would stand in the middle of one of the *two* panels, or do you think you would stand right at the end."

P13 – "I would stand at the end."

P11 – "I would stand in the middle. [*P8* AGREES]."

User Study 2 – Trial 3 – Transcript 1

Researcher – "So what does anybody think happened?"

P19 – "As you walk in the text box that comes up follows you as you are progressing across the screen. It stays basically in the general area that you are."

P15 – "I found that if you were in proximity to someone, your own text would disappear. So I found myself moving to try and find space, even though I did notice that everybody else's was the same, so I could have just read somebody else's."

P17 – "I found it hard when I first walked in to work out which window was mine, because there were lots and they all looked the same. I kind of found it hard, because I could see they were in front of people, but I couldn't see one that was in front of me, so eventually I kind of saw a gap and I went there … my space."

P20 – "I went in last, it was already a crowded space. I pretty much saw what was going on, but most of the time at the beginning I was trying to find a space to get in, although I could have just sat over someone's shoulder and read theirs, but it kind of felt like I needed to try and edge in and find a nice little space of my own to get my own piece of content."

P18 – "I wasn't recognised the first few seconds, so I had to move I think, for the video to see that there was someone else there and the video *window* to pop up. I don't know if it was because I was close to somebody else, or fi it was because I was close to the extreme, so maybe that was it."

P21 – "I found myself moving closer to the screen, to see if it got bigger or stayed the same, and started moving further away. But by doing that I think everyone else found a space, so my box disappeared, so I didn't have a box anymore."

P15 – "Once I realised that if you moved too close to someone else's your box would disappear, I was aware that I didn't want to move out of the space and make other people's boxes disappear while I was exiting, so I thought I'll wait until everyone else has finished reading and do it that way."

Researcher – "So, you have picked up on quite a few points of how this thing works and we'll start un-picking it a little bit. Did anyone particularly notice their relationship to their window, I think this mostly applies to people who went in earlier, you have mentioned this tracks content based on your position. Did anyone notice a relationship with how far away they were from the screen, or anything like that?"

P21 – "Yeah., I went closer to see if there was anything, but I didn't notice."

P18 – "Some of them were higher than others, so I don't know if that's dependant on your height or something. But I saw some of the boxes being higher than mine, so I don't know if others might be taller perhaps."

Researcher – "Do you think that maybe helped with identifying who those people might be?"

P18 – "It helped identify my box, because once it appeared it was at eye level and I was like, yeah this is mine."

Researcher – "So in terms of looking at other windows across the display. What do you think it may have meant. Do you think there was an awareness of, this window belongs to somebody else, do you there is any other information that comes out of that. You did mention the height thing and that does say something."

P19 – "For me, because I was the first going in, it was sort of seeing how the screen becoming more crowded and seeing there were people behind me. So as soon as I was finished I sort of moved backwards to get out of the way."

Researcher – "Do you think that had any effect on your content window?"

P19 – "I didn't notice anything."

Researcher – "So for those who came in later, you have already mentioned you couldn't find your own content window."

P20 – "Yes, I wanted my own content window so I had to muscle in and get one. Or wait, it looked crowded, so I'll wait. It's looks interesting, so I'll wait for everyone else to clear off and there's my chance, so I'll queue."

Researcher – "Did you have a very particular behaviour, your spatial behaviour, that you …"

P20 – "Yes, I started on the side, people had already arranged themselves along the whole thing, so I was going around looking for a space. Eventually found one, I think I got a box, I kind of missed that, the whole thing was kind of moving try to get one. Then as people started moving away, I kind of stayed to get my whole experience type thing."

Researcher – "So you would say you stayed quite far back from the main group?"

P20 – "Yes, I was looking both at the background and foreground to see where I am going to go. Find a spot for myself."

Researcher – "Did anyone else do something similar, in terms of trying to locate a space where you could interact?"

P17 – "I was kind of searching for my screen because I'd noticed that everybody else had one but I didn't have one, then I think a couple of people took half a step either way, so I didn't really have to search, the sort of space opened up for me."

P15 – "I stepped forward at one point to allow more space behind me in case other people wanted to move around. But I kind of wanted to say I'm staying here, so I moved forward. I'll stay in this sector."

Researcher – "Could you say how close you moved in the end?"

P15 – "It wasn't particularly close, it was just kind of, the distance I started out, I kind of halved it towards the screen."

Researcher – "And it was potentially you moving in, you were aware of people next to you, potentially moving in front of them or potentially moving in line with them."

P15 – "So, people were to the side of me, so I thought if I move forward there is the potential for them to move behind me, there is the potential for them to come round the back without them feeling that I am in their way."

Researcher – "So you have both mentioned you were looking for space around the display, do you think there was a minimum amount of space that you were looking for, and how would you define that?"

P20 – “So about shoulder, personal space type size. At least should width, about two shoulder width basically. Enough that it wasn’t awkward for me to get through, but, enough space either side to feel that I would get content. It was sort of approximate to the actual content on the screen. About two times that give or take.”

Researcher – “So while you were looking for that space, would you tend to stay off the back of people if that space wasn’t available in the line.”

P20 – “I would also point out that I avoided standing behind tall people. Both to see and I guess knowing the technology, became visible. Funnily enough, I did not look where the cameras were. I just assumed the screen had to see me.”

P18 – “I did look at the screen with the coloured dots on *secondary Client monitor* because my screen wasn’t appearing, so then I looked on the second screen to see if I was being tracked, and I was thinking, ah yes, then I appeared.”

Researcher – “Did you attempt to interact with the Kinect camera?”

P18 – “No, I didn’t know where it was. I was just looking in the red dots to see where I was and then my screen …”

Researcher – “So a sort of out of band verification of how is this working?”

P18 – “Once I got the screen, I was like, I am not moving at all, because finally I got the text. I noticed you moving closer and then further away **, but I thought, no no no, I got the text and I am not moving.”

Researcher – “One last question. It has been noticed that some o the screen were disappearing, for various reasons. Would anyone have an idea why that might be. It may have been touched upon already?”

P18 - “Because of someone else, because of being blocked by someone else, because of something like that. Or because of two screen becoming close, does one disappear.”

P15 – “It seemed they couldn’t overlap, so as they became closer one would disappear, but I didn’t notice which one, whether it was the moving on or …”

P19 – “I wasn’t sure if it was the, I thought perhaps my window, because I had gone in first, had timed out perhaps. Because I had gone through the first page, gone through the second page, I thought the perhaps afterwards it was gone.”

Researcher – “Did you notice anything about where you were standing or how far away you were, or if there were people around you when it finally disappeared?”

P19 – “I was standing reasonably close, I mean not hugely close, but maybe one third of the distance that I was standing at the beginning, which I had gone to because more people were moving in.”

Researcher – “Was this something other people did, particularly those who moved in earlier, was to move closer as other people arrive? *P15 – That’s what I did*. I think in your case the strategy was to really stake a claim and say, this is my space.”

P17 – “I think I probably did that when I saw a gap, I kind of saw the gap and I went a claimed my space. I didn’t kind of move closer because more people came, because I was one of the later one. I didn't move closer because more people came, I moved closer to kind of claim my spot."

P18 – "I didn't notice that the last screen disappeared because I left before the last screen disappeared, I figured I had just finished the text so I will go. I did spend a couple of second without knowing what was happening, and then I saw *P17* leaving, so I will just go."

User Study 2 – Trial 3 – Transcript 2

Researcher – "Would anybody like to say what they think happened?"

P20 – "I went in second, and pretty much the only thing I had to care about was where *P17* was going, they went off to the left, I went off to the right. So I quickly just said, alright, went off to the other side, read what I wanted to read. I was pretty much there in a comfortable position, until I started feeling a lot of people crowding me on my right, left …"

P18 – "The same with me, but I went the other direction, so I went to the right, and did the same. The I noticed someone else, I am not sure who, came in after, a few seconds after me, and the screen was disappearing and I think because it was colliding with mine, so I moved a little to the right so they could have their screen."

P17 – "I did that as well, I noticed there was someone trying to get in and their screen was flickering. So I moved over a little bit, but I think I moved too far and then made someone else's screen disappear, so I moved back."

P21 – "I was one of the people who came in a little bit later and I think I found people moved. I stopped where there was enough space, but there wasn't enough space for my screen, so it disappeared a few times, but people were very nice and they moved to the side."

P15 – "I was the last one in, and everyone else was kind of in a line, and I was behind. So I kind of gauged the distribution, so I though ok, this is the biggest space and I'll go and stand there and see if there's enough space for a screen. Then of course, the line started re-arranging itself and everyone was shuffling and there wasn't any more space, so I though, ok I'll come back and wait a little bit, and possibly when someone had left and there was a little bit more space I moved."

P19 – "I was also one of the *flickerer* kind of people, and when my screen first disappeared, I tried going closer and going back to see fi that would help my screen re=appear, and then people next to me started making a bit of space to also help getting it back."

P16 – "I was one of the first who came to the screen, so when we, first I looked for the blank space and then when I found the blank space, I looked left and right to see if I had space or not. So when *P20* left, I had space on my left and then I could read it."

Researcher – "So when you first entered, you said you were third or fourth *P16 - Yes*, there was a lot of space?"

P16 – "Yes there was a lot of space, I could chose to go to the left or right. But I think the right side is a bit crowded so I went to the left side."

Researcher – "So you mentioned when *P20* left you had more options, so you moved in to the new space."

P16 – "Yeah, so I could give more space to someone."

Researcher – "So you wouldn't let people take *P20* space, you would more naturally move over."

P16 – "Yeah, because it was in the corner, so I was thinking it was more in to the corner, it was moving out the way."

Researcher – "Do you think you would have done the same think in the last trial, given that you entered from the side. Do you think where you entered the space, where other people entered the space affected that decision. *P16 – I think so*. Do you think you maybe would have done that anyway, whatever the situation?"

P16 – "I don't know, because …"

P18 – "For me it was different. Because the first time I just wanted to see the screen as soon as possible, so I just got close to this side, the left side. But this time, it was different because I was more conscious about the other people and where I should position myself, not to bother who was already there and who was coming after me. So that's why I chose the other side."

Researcher – "So the more you learn about the group and about how the system works, that's actually affecting your behaviour."

P18 – "Also knowing that there are already people coming after you, and that there are already people there."

Researcher – "So in terms of what you saw on the display and knowing that other people were coming, do you think that altered your behaviour at all? Particularly for the people who came in earlier."

P18 – "Yes, because there were lots, well not lots but several people were coming after me, so I basically wanted to get out of the way to give the maximum space to the next few people who were coming in. And afterwards I wanted to have my screen away from everyone else."

P17 – "I was first and I didn't really think about anybody else."

Researcher – "Where did you stand?"

P17 – "Slightly off to one side, but I think that's partly because there's a split in the middle, I probably would have stood in the middle, but there's a gap in the … thing *join in the screen*. I just moved to one side and I just stayed there."

Researcher – "So your decision to stand in the middle, how did that come about?"

P17 – "I think it's just because that's, we were coming from the front of it, the middle seems as good a place as any … it was closer. The shortest side of a triangle."

P15 – "Maybe imagining this was in a museum, because that's what it said in the text *introduction document*, just thinking the difference between the entry point, this time it was more obvious the text was tied to the person because it moved. Where as this, if I was coming to this for the first time, I'd notice that getting close to the screen would make it do something, but I wouldn't necessarily thing, oh that's my content, I would think, oh I've just triggered something. So if there are already people there, it would be different I think it would depend on if there were already people there or not. If I thought it was a personal experience or a more general …"

Researcher – "So did anybody particularly feel like the window that was shown was their window?"

[GENERAL AGREEMENT]

P18 – "Much more than the first time. Because the first time I was having trouble getting my window, but this time I got my window and it would follow me and that was. I did try to come closer and further away from the screen but I don't think that was doing anything. I did notice some flickering, but I don't know if that was because I was going out of the area or something."

P21 – "I tried reading it as I was walking, but I found that I couldn't, so I stopped."

P19 – "I would say on the first one, where I was also the first on coming in and walking along the screen quite a bit and dragged the screen with me, I had more of a sense that the square was really sort of mine and interacting with me. Whereas, with the second one coming at it from the front a bit later, so basically slotting in to one of the areas, it was a bit more like a screen that gets triggered when you get close to it and not really something that gets tied to me."

P15 – "That's a much more succinct way of saying what I was trying to say."

Researcher – "Is there anything anyone want s to add to any of these points? Anything anyone finds particularly interesting or they're not sure about at the minute?"

P19 – "I think as far getting a distribution of people in front of the screen, coming at it from the front in the second trial, had more of a tendency of easily saying this is where the space is, and had more of a tendency of a natural left, right, lefty, right distribution of people going."

P15 – "Yeah, it was like you're coming towards something, and you notice that you can interact with it, so when you notice that when people arrange themselves to do the interaction. But with the other one, the other one felt more like transiting, and it might catch your attention."

Researcher – "Now that you have had two trials with it and you are becoming more aware of what is going on under the hood."

User Study 2 – Trial 3 – Transcript 3

Researcher – "Would anybody like to say what they think happened?"

P17 – "It was kind of the same as last time, except the windows behaved differently. They didn't disappear, they kind of went behind, and in front some times."

P21 – "They dropped in opacity, and kind of got a bit smaller. I probably broke it by walking up and down at the back, my window was going big and then small and behind … and then it crashed."

P15 – "I saw someone's fade, or go opaque. I saw somebody else's box fading, or coming in to focus, I can't remember which it was. I don't think I consciously remembered, oh the boxes are behaving differently. I just saw the boxes flickering."

P18 – "Did anybody else's boxes have a shadow. I was the first one and I think mine had a shadow, I don't think I saw anybody else's have a shadow. I don't know if there was a problem or something, and a few seconds later it started flickering for me, and I wasn't moving, I didn't do anything differently, it just started flickering."

Researcher – "I feel that is probably a bug in the code, there has just been some misalignment in the system."

P19 – "I had the feeling that it didn't pick me up from as far away this time, I had the feeling that I had to move closer before it would pick me up this time. And then I noticed that it then seemed to do more of the zooming in kind of thing, starting from smaller and getting bigger kind of thing. And then more getting mush by people next to me, and then having to move more to the side to have it come back."

P17 – "Did it, I kind of got the impression that the windows needed more room. I don't know, it kind of felt like the gap that I was in would have been big enough for a window, I don't know, it kind of felt like it needed a bit more space to come forward."

P20 – "That is kind of a similar feeling that it was interacting, so came in last and found that there was something, a bit of free room off to the side, and tried to crash my window in to the side of someone else's, but I don't think it happened. I don't know, did yours *P19* disappear while I was on the way to it."

P19 – "no not quite, I started to move a little bit to the side to get out of the way of yours, but … I noticed what you were trying to do, boxing between boxes."

P20 – "It was just flickering in and out, mine was …"

Researcher – "Did you particularly notice how you were spatially aligned to each other?"

P20 – "I think we were shoulder to shoulder *P19 AGREES*."

Researcher – "And who, I imagine one person began to shrink?"

P19 – "Yeah, I think mine began to shrink a little bit, and then I began to move a little bit backwards … at which point it crashed."

P20 – "I also figured out that crashing the windows together would also crash you and me together."

Researcher – "Did anybody particularly notice how the windows were interacting and perhaps why they were interacting? I saw a couple of people actually playing with the system if anything."

P17 – "It felt like the moving ones were the ones that got pushed to the back, people who already had the screen were the ones who were standing still. I was trying to find a space but their windows were taking precedent, so I was kind of always behind everybody, but when I found a space it wouldn't quite come to the front because there wasn't enough room, so I had to try again and move around a bit."

P15 – "I was trying to test if you could be selfish with it, so I thought I would go in, find a space and sit down to try and anchor the screen long enough to read it and leave and see if other people's had to be kind of secondary then. It worked really well for a little while, so I thought I would just kind of stay and it will come back. And it did, but I never, with that technique, got on to page two of two. The screen was moving, but I never got the full experience."

Researcher – "Did you notice what happened with other people's windows?"

P15 – "I noticed that other people's window's were flickering, so I didn't know if my decision to sit down was having a detrimental effect on other people's experience, and then I also noticed at least one other screen moving, and I didn't notice if that made mine disappear."

Researcher - "Did you particularly notice any windows going past where you were, left to right, right to left?"

P15 – "Erm, definitely one going past, let to right I think. I don't think anything ever went behind my screen."

Researcher – "So those people who were moving around, I think I saw some people running around side to side at one point, could you maybe infer what was happening with your window in relation to other people's windows?"

P21 – "Well yeah, it was anchored to me and basically as it was coming to somebody else, it would drop in opacity and get slightly smaller and like, allow it to transition through somebody else's screen without disrupting them, and then come back on the other side of their screen and return to normal size and opacity. I found that much more interactive than the previous one's where it disappeared and just like appearing that way, was like some interaction with other boxes, but I was behind everyone as well, so I don't know if I was in front of them if it would have done the same thing, or if it would have stayed big and other people's would have got small, I don't know if the actual physical distance from the screen affected that or not. But I didn't want to run about in front of everyone."

Researcher – "Is there a particularly, were you actively playing with the system?"

P21 - "Yeah, yeah, I wanted to test is that how it works. Does it, I was over on the left, and it seems like it gets smaller, like how I described it. So, does that work across the whole thing, so I walked down and ten back."

Researcher – "Why did you feel you didn't want to go in front of anybody?"

P21 – "Well then I would physically be obstructing people from seeing the screen."

Researcher – "So it's the basic kind of social convention. So in terms of where people where actually standing, their distance from the display, if they had been further away would you have potentially gone in front, or was there something to do with maybe the number of people and where they were all standing, their configuration basically relative to the display."

P21 – "I think if it followed your eye line, then I would have felt easier going in front of somebody and it going a bit lower, so like moving about the space that way. But I think just going in front of somebody in any case is just a bit rude in any situation, especially in front of a screen."

Researcher – "For those people who were at the display, potentially a bit earlier and had actually anchored a position for themselves, what do you think the effects of the new kind of interaction were? So for instance, if your standing there reading something and a window comes in, perhaps left to right and then moves on, did that have a particular effect on your experience, or is there some kind of …"

P18 – "I was in the corner so I didn't notice that, but there was a lot of flickering, so I thought I was doing something wrong so I didn't do anything at all, so I even stopped moving to try and make it stop being transparent and flickering. And then I noticed that even with the flickering you can't keep reading, but I don't know if it re-starts the counter or something, but it just doesn't go to the next screen, so I just spent the whole time re-reading the next screen."

P17 – "I think I had quite a negative experience with this one, because I kind of had a screen and I had space, but then I noticed it coming in and it was kind of fading out, so I noticed there was somebody there, so I then tried to move to make some space for them, but by moving I kind of moved in to somebody else's space so my screen disappeared. But by then the other person had kind of got their space, so I couldn't go forward and I couldn't go back, so I had kind of given up my screen space by trying to be kind and then I ended up having to walk all the way to the other end of the screen to try and find a gap, but there wasn't a gap so I kind of had to go back but there wasn't a gap, so I never really got my screen back, because everyone was hogging all the space, and I was only trying to do the right thing."

Researcher – "Right, so you did actually brush on tot eh subject I was fishing for a little bit. You mentioned there was an animation, another screen appeared and it began to animate, and you understood that there was another person near, or behind you potentially, and they were then trying to use the screen, and this had a knock on effect to your behaviour."

P17 – "Yeas, I was just trying to give them a little bit of space, but it kind of backfired. I should have just stayed."

P15 – "But then I was trying to be deliberately selfish and stay still, but that didn't work either, because I don't think I barely noticed other people's screen when they weren't directly impinging on my own. So stuff moving behind or whatever, I didn't really mind, but what I noticed is when my screen completely disappeared, and when it came back and I've got to read the same bit over again and I can't make it go forward, so I was kind of playing the opposite game."

P20 – "My intent was to be deliberately obnoxious, and disappointingly it wasn't effective on the content, but it was probably very annoying for the people I was shouldering in to. You will get people like that."

Researcher – "Were you physically interacting with people or more kind of impinging on their personal space, or were you more kind of …"

P20 – “I was focussing on the screen, but I got in to their personal space effectively. I guess I could have been in front or behind I guess, or on the plane towards the screen, but there wasn’t any zoom-in-ness so there was …”

P19 – “Yeah, I was right next to you and I didn’t really notice my box going behind yours or yours going behind mine.”

P20 – “It wiped your content off the screen though.”

P17 – “Were you quite close behind.”

P19 – “Yeah, physically we were quite close, perhaps the same distance.”

P20 – “Yes, shoulder to shoulder.”

P21 – “I would be interested to see if each person had different content if each person would have more of a feeling of ownership, or, selfish about seeing that content. Because if it’s all the same you can read somebody else’s if it disappears.”

P20 – “If I was half way through a five minute video that had my face up on the corner of it, I would be very annoyed if somebody, I mean fi I lost it and I couldn’t get it back where I was kind of thing, but that’s more of a content discussion.”

Researcher – “It’s still very interesting, don’t get me wrong the points you are raising do really help, because I did mention, you have a window and it maps to you, so you feel ownership to this window. But knowing how that fans out in to a more inclusive picture where there are more people in the space, is great because it really helps to align the next study.”

P20 – “The only way to claim ownership is to do a little dance, to get the window to respond.”

P21 – “Centered in the interaction of the content instead of the actual content itself.”

P20 – “As soon as it did that I thought, that’s my one, right I can do stuff with it, but didn’t always react as I, I wasn’t always left to right, as I went up and down … I didn’t notice anyone else.”

Researcher – “It doesn’t come back down, it come up to your head high. For instance, you *P15* are actually the second person to sit down, so I was actually curious about, where you sat, why you sat there. You have mentioned it was to anchor the position, and how your experience then was because of sitting.”

P15 – “I deliberately went closer to the screen, I had decided before that I was going to try sitting to see what happens. Because it was maybe just thinking about museums and galleries and that tendency, when you’re looking at a piece of art or something and you want to kind of focus on that one, you might sit down and say, no I’m, not passing through I’m focussing on this thing, and people will move past you. So I through, so I kind of thought that I’ll try that and seem what happened.”

Researcher – “That’s quite an interesting analogy, I’ve found that seating in museums and galleries tends to be quite a long way from the actual piece itself, allowing this traffic. You *P15* went the other way with it and went quite close.”

P15 – "maybe more analogous to watching TV or something, because your saying right, I'm focussing on this screen and what's happening on this screen."

Researcher – "Do you think your position made a particular statement about the space, and like we've said, public space?"

P15 – "Yeah, I think I was saying I'm here, I'm staying I'm not going to move for anyone. If you want to do something you've got to move around, I'm going forward to allow that to be possible, instead of sitting back to allow people to go behind."

P20 – "Someone has mentioned, their content doesn't get scaled to the distance right."

Researcher – "no, but there is a reason for that at the time being."

P20 – "I just had the feeling that the closer I went the smaller the content would be, and therefore I would take less real estate on the screen. So, the closer I went it would be more private and I would be less obtrusive. But the farther away the content becomes big and I am taking up a lot more of the space, my personal area becomes bigger. Which probably influences the fact that we all pretty much go to the, pretty much, best distance from the screen, so we all end up pretty much shoulder to shoulder most of the time. If it's scaled we would probably be a bit more staggered. We'd probably end up quite close because it's trying to get …"

Researcher – "There are a lot of very interesting questions in there, which we're going to step over for now, because it opens up a real can-of-worms, in terms of how these kinds of displays could work. The point you *P20* raised about getting very very close and having you text take up less space, I don't know how much you experienced the animation of people passing around you, or how much you imposed that upon other people yourself. I don't know how much you saw it across the display."

P20 – "I was on the left edge, so I never crossed behind anyone."

Researcher – "So for instance, how do you think you would feel about other people, for instance if you were more central. I think you *P20* have been to the side for a lot of the study. And you were very close, with a small window, how do you feel that other people passing around in the space *P20 – BEHIND ME*, yeah, probably because you were very close, how do you think you would like that animation to work, someone passing behind you?"

P20 – "I would assume the content, because I would be very close to the screen, would be very small. I would expect someone else's to go above me, because if it goes below they won't be able to see it, if it goes behind they won't be able to see it. So if the free space is above, I assume that's where the free space is, that means they can keep watching the content. Because you *P21* mentioned it was hard to keep reading the content when you were moving. If it's video, I wonder if it might be a bit easier, if it was text I imagine I wouldn't want to walk and read."

P21 – "Yeah, you wouldn't want to do that anyway."

Researcher – "Ok, so we're slightly off track, I can come back and go over some of these points. So, the point you raised about it going over, is one of the points about it going over is one of the points we will step over. More about your personal space, the relationship of someone else's window to your window and your personal space and your personal awareness in particular. Maybe there's not a point to get out of this, there is appoint of discussion or point of interest, perhaps for the next study."

P17 – "The only thing that comes to mind, is that there's not really much point in making the screens any smaller than your comfortable personal space, because everyone's about half a meter across and then there's about twenty centimetres on either side, it kind of feels comfortable, or whatever the numbers are, because you can't even get another body in there."

Researcher – "This is the kind of tie that I'm kind of looking for, I think this is very much the kind of thing to think about for the next study."

P20 – "Say you were nose to nose with the screen, hypothetically, the content should be the size of a smart phone, the content should be this big, because if it is any bigger and I am this close, then I have to move my head to see it. Again, a bit of a tangent, I think a three point five inch screen at this distance form your nose, equates to a thirty inch screen or something like that. But then again I don't really want to get nose to nose with a big screen for any reason, so I think the distance you *P17* mentioned seems about right, square with your shoulders to the screen."

Researcher- "So we're getting in to the realms of presentation, which is how you present the content and how this will influence how and where you interact with the content from. So this *Content windows* is all locked to, you know, this definition at the minute, because it will result in a certain kind of presentation basically. I am more interested in how you are interacting with each other, so I am not doing too much at the moment to investigate presentation or real-estate, which you've actually just touched on both of those, but we'll step over those for the time being. So I think the things we'll focus on at the minute, is things like, if you were very close, how do you think that, if my screen was appropriate for my distance *P17* mentioned there was no need to do that because there was no physical space for someone to then walk around you, and the knock on effect of that is that you're all forming a line. You have all gamed the system to the point that you know how it works, you know how to interact and you're forming this line. I'm spoon feeding it a little bit, but you've all got there and what's now interesting, or very interesting, is how this changes your behaviour yet again. So there's an awareness of how the screens work and that you have your own, and as you're all moving around one another in that space it's changing the way the screens start to interact with each other. So for the final one, it will be more focussing on your personal behaviour and how that's affecting what's happening on screen, why you're making those decisions and general bits that you are finding interesting."

User Study 2 – Trial 3 – Transcript 4

Researcher – "Would anyone like to say what they think happened that time?"

P17 – "It seemed very similar to the previous one."

P18 – "I did notice that when I came in the screen was lower, but then as I got closer it went up, but then it wouldn't go down if I went further. It would just stay at that height. And then I had again problems with flickering and the counter again, so I stayed on the first page again for a long time. Then I went to the second page, but my window crashed with someone else, so it again started form the first page, so it took me a long time to get to the second page."

Researcher – "I think again, these are caveats of the system that are just kind of creeping in. It may be an issue of the conditions today, the cameras do just play up some times."

P17 – "I think I was quite close to you *P18*, I deliberately went quite close to you this time."

Researcher – "There are also issues of occlusion, with …"

P18 – "It's ok, if it flickers and then goes out again, it's not a problem but it's the fact that it starts again from the beginning that's the problem, because then you have to read the same text again from the beginning, that's the problem."

Researcher – "I'm guessing there was nothing overly crazy?"

P15 – "I think there were lots of things I couldn't quite really explain, because I was trying to focus instead of reading the text and focussing more on experimenting. I noticed at one point, the box that I thought was mine disappeared and then reappeared lower down, and I didn't understand that, and then at some points the box was doing things and I thought there must be someone behind me and I looked around and there wasn't, but then I was trying to work out. And then the same thing with the text moving forward *Page 2*, but this time I thought I don't care, I'm going to read his box and as I can see he's on page two, and then I've done that bit and it doesn't matter."

Researcher – "Yeah, I think I spotted all of those moments, and I think they were all down to just system issues, where particularly if you're at the extreme of the screen, you are out of range of the other two cameras and you are kind of close to one, so all of a sudden it can get quite confused. I think the other person was actually me walking through and I though, woops, I'm a little bit close there."

P18 – "I did the same as you and looked around to see if there was anyone else, but no I was alone, and it was something with the screen."

P20 – "This time I went in first, which was new. Walked up, this time it allowed me to find optimal distance, when before I just went to the back to find a window. But this time, two thing, when I felt I was done I basically had to look around, from all the content moving around, I was like, there's people behind me, I wanted to move backwards carefully without interrupting anyone's experience. And the other one is abit close to content again, I spent a lot more time in all of these, I spent a lot more time worrying about where I was an d what I was doing, instead of actually reading any content. It was not juts, now that I was alone I could jiggle left and right to see that it was actually mine, to see what would happen. A few people were popping in left and right, I wasn't really watching what was going on, are people coming too close, etc. People were coming around me things like that, and I'm just wondering, apologies for jumping the gun. If now you came up and asked me, you saw X piece of content, what was it."

Researcher – "Why do you think you were distracted, do you think it was because of the briefing, or …"

P20 – "Erm, on one hand, it was discovering what is this and what can I do with it before seeing the content, and then the fact that other people could interfere with my experience and I could interfere with theirs, you know, triggering my peripheral alarm, let's say, every five second, somebody’s behind me, or something like that, it’s kind of distracting. But that happens anyway in museums, you get engrossed in a plaque or something and suddenly there’s ten people behind you. But this time I had, they’re behind me, maybe I don’t care. But this time there’s the content in front of me, kind of flashy lights.”

Researcher – “How close were you to the display?”

P20 – “I walked, I saw it come in, it was too far away to begin with, got closer, up to the point where it was comfortable. I’m not too sure where that was, but same as last time where I got to the point where I didn’t need to move my head around, I could just read the text comfortably. It was approximately shoulder width let’s say. If the text was smaller it would have been closer, if it was video it wouldn’t really matter.”

Researcher – “I’m just curious, you mentioned you had a lot of things going on in your peripherals.”

P20 – “I’d gone in first, so everybody was piling in behind me type thing, that’s what it felt like.”

Researcher – “Did you, or do you feel that moving closer would help with that?”

P20 – “I felt like instinctively I wanted to do that, If I go closer I will take up less space, give them more space, but the way it is basically, when you stand somewhere, you are taking up a rectangle of the screen from, orthogonal from the screen. That’s all yours, they can’t really do anything. If they can be above, or go down and sit down in front of me, maybe that would give more real estate, but as it was I wanted to make myself small.”

Researcher – “This is why I mentioned simply moving closer, but you didn’t or you chose not to.”

P20 – “I don’t think I did. I felt like I had to or want to, instead of reading I was looking left and right to see what was going on. If the content had have been getting smaller I probably would have done it.”

Researcher – “So that was more, you stated there was more going on in my peripherals, it was distracting, it was causing me to physically look around.”

P20 – “Not necessarily didn’t like, but yeah, it was something to keep track of. It wasn’t just a threat, like something coming. It was like, I’m reading this, it’s changing at a relatively slow pace, is that something I’m supposed to look at. Is this whole thing one video, I don’t know I’m new here.”

P17 – “it’s like your hunters peripheral vision, you know. If you see movement in your peripheral vision, it attracts your attention. I think that might be a choice, there’s a lot of movement, a lot of flickering going on. I think that might just be a choice of the animations and things that were chosen. You could go for something much subtler and it wouldn’t be like, as distracting.”

Researcher – “So just based on that conversation, did anything pop in to anyone’s mind. In terms of where people were standing or what was happening on the display in terms of animations …”

P21 – “At one point there was, I noticed there wasn’t that much space between two screen and I was able to go behind and I was able to get my screen small and get it to fit in and I was happy to just read that and the people on either side noticed that I was there and they moved to the side to let it fit in and it got bigger. I wasn't intending that to happen obviously, I wasn't intending for people to move, but it did work in a kind of passive aggressive way."

P19 – "When I came in I took position on the right most position of the display and I initially, there was a good amount of space to the left of me, and when I came in I noticed there was the box coming in from the bottom of the screen just moving up towards it. The when the next person came in next to me I noticed that their screen seemed to be lower than mine, so I tried a bit of going down myself or going backwards to see if I could manipulate the position of the box myself in terms of the height. Erm, and then a bit later I decided to try playing around moving around behind other people going across the screen going towards the centre area and seeing how I could move in to the back. When I was in the centre area it was a bit smaller, so it was a bit in the back, but I decided to just keep it that way and just read, but I noticed the text wasn't complete in the box, because the font wasn't quite scaled with the box."

P15 – "yeah, I noticed that."

Researcher – "So in particular the people who, this has not come up twice, your boxes have been animated and your content has come up smaller and you have been reading that happily enough. But those people either side, so those people who noticed there was a box sitting there, you maybe can't see this person, what did you then do, as you mentioned *P190 & P21* you were standing behind those people. Was the knowing there was a box there, knowing there may have been another person there, was that influencing your behaviour?"

P17 – "I think it did in the previous one, but I don't think it did in this one."

P18 – "I moved in this one, because I thought in this one I was taking space so I moved back and then my screen disappeared. Then I moved to the left corner to see where the screen was."

P17 – "yeah, you did what I did in the last one. I came in and then you moved over to make room for me, and then your screen completely disappeared."

P18 – "It didn't disappear, it just came …"

P17 – "Faded out."

Researcher – "So, in particular between the first two and the second two. Where in the first two the screens were disappearing when they were beginning to interact, and in the second two where they were animated, how did people find that? What the major differences were in those cases."

P18 – "I liked the fourth one, because as you were entering the text appeared at your eye level and then goes up with you, and then there's no flickering no disappearing, so as *P17* said, it faded, so then at least you still had contact you knew that that was your box, you could still move around and it would follow. In the first two it would just disappear so then you had to find your place again to make it pop up."

P15 – "Yeah, that felt slightly more adversarial, like you were competing with the other people for the chance to read, where as in the second one *trials* it felt slightly more … sorry, competing but also waiting your turn. If you came in behind someone it was kind of like, ok they're engaged in it, so I wait and I do it. Whereas, certainly the last one, when I wasn't sitting down, it felt like there was more opportunity for collaboration, ok so it felt like how do we orientate ourselves around one another so you can both use it simultaneously. I don't think we succeeded did we, we were trying to co-ordinate but whatever we tried didn't quite work."

P20 – "Three dimensional Tetris, that, as soon as we get more control over size and say perspective of the content, we'll try and self-organise so that we're all going to see something, I can imagine that happening. I can imagine someone breaking it. I can imagine people expecting all the kind of dynamic layouts, HTML5 type thing. People expecting the content to expand to grab the maximum amount of size and re-organise itself to people."

P15 – "Yeah that's what my imagination was doing, oh, wouldn't it be good if you could kind of, if you all just have dots and you could move your sot in to a space and it would expand to fill the available space and that sort of thing."

Researcher – "That's the future work section right there. So in particular, from an individual perspective, how did you stand in the space, be aware of the display and be aware of other people in those two cases, so the disappearing versus the animation?"

P17 – "I think I had more awareness of the people in the animated case. I think when the window, I think when, we worked out quite quickly in the disappearing case if you stood still then it was the other persons window that disappeared."

P15 – "I totally didn't get that."

P17 – "but in the animated one, perhaps because it's more distracting, there's more going on and you can't, you couldn't ignore it, you couldn't carry on with what you were doing, you had to do something about it almost. Maybe, I think, it's hard to contrast the two."

Researcher – "So in terms of how you were aware of other people, in the first trials would you actually make the effort to look around and find out where the other people were, and potentially why there was this strange interaction happening with your window and somebody else's. Did it matter where other people were, or was it just important to just maintain your window?"

P17 – "I'm definitely a window hog. As long as I've got my space. If I could move, then I did, but I didn't sort of, I wasn't actively looking to …"

P18 – "For me neither, so what I did is always go to one extreme, go to one side or the other so I would bother the least amount of people. You know, only people from one side, so that way I could focus on the screen but also know I was causing the least trouble to everyone else."

P20 – "I felt self-conscious, like at a supermarket [GENERAL AGREEMENT] trying to pick something up and there are people behind you. You move to the side so they can see what's on the shelf as well. You don't want to go, but then they … If it was a big mirror and I could see people coming up to it. Normally you couldn't, but with this, content suddenly popping up so you know someone is coming."

Researcher – "Ok, so that was a great analogy, would other people actually say they actually felt similar to that, or …?"

P21 – "I felt myself interacting, not just with my one, my screen, but with other people's as well, and then indirectly almost with the bottom, the physical presence, or is it secondary, but I think it was because I was concentrating on the screen, and I wasn't always like, going to want to read the …, but what happens if I go closer or go behind, and that caused ripple effects of other people interacting."

Researcher – "So again, more playful investigation of the system, as opposed to actively engaging with the content necessarily? [P21 - YES]. Yeah, so what I'm more sort of getting at a little bit, in the first set of trials where the images, windows were disappearing, how did you maintain an awareness of the others or anyone else in the space, if you were interested in anyone else in the space, or just engaging with the content. Or vice versa, if you've got a more playful, I want to see what I can actually do with this thing, in-spite of everyone else in the space, it seems there are two different perspectives on the same interaction, but it's very much different kind of view points. Would you find it interesting to know where other people are, is it important or does it just not matter?"

P15 – "I think I felt it was important, particularly in the first case, no actually in the second, well when boxes disappeared, it felt like, there's a minimum amount of space that I require to do this thing, and if that's not available, erm, or it's being interrupted because of the number of people in the space, I have to wait until someone leaves, and then I do it. So I think I was aware of people, just in that sense of making the system work for me. Where as in the latter two, it was more about how people were in relation to one another, and how their experiences were intersecting."

Researcher – "Right, so I think we'll just put a pin in that for now, it's a bit like flogging a dead horse, there's only so much you can pull out of these things. Erm, I mean the only other thing would be the entry position, one from the side, one from the front. I don't know if people actually noticed the strip at the back where you're not actually detected, which is where the entry point actually is in both cases. Then do you feel that entering from different places might have affected how you then used the display or how you might interact with it?"

P17 – "I think my strategy was to go to the closest bit of the display, so yeah, where I entered made a difference because that effected where the closest bit was. I think if you enter from the back you get a better view of the screen as a whole, so you get a better situational awareness. Yeah, but I think that was it, the closest bit changed and you can kind of see a bit more."

P15 – "Yeah, I was going to agree with you, when you come from the back, you get a sense of it as assort of holistic picture of where other people are and where the gaps are and sort of thing, whereas it's sort of slightly less obvious when you come in from the side."

P19 – "Yeah I would agree with that, also, just understanding where people are is much more obvious when you are coming in from the back."

Researcher – "So, just narrowing the angle to the display, so entering almost directly against the display would make things much more difficult in that sense."

P21 – "I think as a single person, or as the first person coming in from the side, that way you're going to realise how it works immediately, as opposed to coming in straight ahead, where it will just be static, there's no movement left or right, so it might be more suited to a corridor type affair."

P15 – "And it would stop you because it would be tracking you and you would think, oh that's interesting."

P20 – "Definitely it would stop you moving, sorry, I would expect it, something like that, to work, regardless of you know, point of ingress, but I would expect it that if it was in a corridor which sounds like a very good place for it, it wouldn't be like it is here, with the curtain, where I go in and then there is a screen further along, I would be able to, say, it wouldn't be hidden from view, I would be able to come along a corridor type thing, see what I mean. I wouldn't walk in to a room or corridor and suddenly, ten feet to my side there's a screen, it'd be, imagine if it's in an open space or on this wall for example and I came in from there, I would have full view of what it's doing with people and without type thing. So, and I would expect it to work if I was coming from over there or over there, it, it would definitely be a better experience if I walked in and I saw something following along it. Or, if I came in from this side and I saw a massive thing saying hello *P20*, then I would know it was for me."

Researcher – "So you want to be able to see it all, but also be able to have interactivity as you walk past it as well?"

P20 – "As in, not the coming in from the side, this, layout as it is seems to be the, don't know if it's sub-optimal, but you're basically coming in at a very, forty-five degree angle every time, if I go, if we could come in at [Researcher – Shallower angel] Simulating a corridor basically. Where I imagine this could be …"

Researcher – "In particular, when you *P21* entered, you entered quite early from the side?"

P21 – "I was like, second I think the first time, and then near the … yeah, I could see that, I could see it track me."

P15 – "Yeah, and I was third, and I could see it track *P19 & P21*, and I was like, oh yeah, look at that."

Researcher – "And I guess, seeing as it's mapping perpendicular to where you *P19 & P21* are, or orthogonal to where you are, did you notice that interactivity going on, or did you have to get in to the space more before it became apparent to you as leaders of the group or procession?"

P21 – "Yeah mean like, coming in from the back."

P19 – "Coming in from the side."

Researcher – "Yeah, coming in from the side."

P21 – "Yeah it's much more immediate coming from the side instead of coming from the back when there's nobody else there."

User Study 2 – Trial 4 – Transcript 1

Researcher – "Can I ask, would anyone like to say what they think happened in that trial?"

P25 – “I think as we entered, each camera located each us and displayed and displayed the message in front of us and then it was detecting if we moved or not, and if we moved the message was moved in front of us.”

P22 – “It was very cool. I came in and I wasn’t sure if this side *far side from entry* would do anything, but then it popped up and it seemed to recognise where I was and there was the content.”

P25 – “I think it might have caused people to go to one side at the beginning, because everyone could see there was something here so I walked in like this and it was just here and multiplying here, and the other side was empty.”

P26 – “I walked in and I saw that everyone had the same text but I still wanted my own, so instead of reading their I walked here where there was no-one to get my own little pop up and I felt bad because *P28* didn’t get one and they started walking behind us and trying to get seen by the cameras. I tried to move away so there was a space but, it didn’t work.”

P28 – “I found, because I came in last, that instantly I was trying to find a space, so I came over this side, where as you *P22* were saying, people were mostly clustered that side *left* and I was, at first, finding that because there wasn’t a space for me directly at the screen that I was trying to position myself in between the heads of people and where someone else’s text box was, so I could get a good line of sight to read them. And sometimes, obviously it didn’t go on for very long, it was kind of frustrating because then someone would move and then their box would move with them and I was having to adjust my position to keep that kind of line of sight.”

P23 – “Same fo me, absolutely the same for me. I actually didn’t, I found a place where I could stand because I had space to read and one box that didn’t move.”

P27 – “So, I had the feeling as well, because I had the feeling I was blocking many people that were behind me, because the box that was in front of me and I just stopped and tried to read the text. So I think it would be better if the text moved slightly to the right, because it would then motivate me to move slightly to the right and not stay there.”

Researcher – “This is the next study. Did the feeling that you were standing there blocking other people, did that change your decisions?”

P27 – “Not really, because I tried to read the text first and then, then, move it a bit. It made me a bit uncomfortable, but errr, I tried to read it, the text before I move.”

Researcher – “you were uncomfortable knowing other people were around you or …?”

P27 – “Yeah, I just rushed for one or two seconds, it was not a convenient feeling, but …”

Researcher – “How did you know other people were around you?”

P27 – “Errr, you feel it. If somebody is looking behind you, if somebody is coming close to your personal area.”

Researcher – “Do you feel you were looking around you, or do you, just focus on …”

P27 – “I just focus on the pop-up box.”

P28- “I just want to kind of add to what *P26* said about, I think you said you wanted your own, so you came over in to a space. But I had the feeling as well, feeling slightly short changed in a way, that I didn’t have my own text , even though I could read somebody else’s, but there was definitely that sense that it was theirs and not mine.”

P23 – “In my case I found it kind of, rather confusing that there were three boxes. If there was one I could focus on one, but I was kind of like, am I missing something.”

P24 – “Yeah, I did kind of look at other people’s boxes and see what was going on.”

P25 – “I was looking in other boxes as well, but I couldn’t find any sort of narrative, or relation between them. So I don’t know if I am looking at something I have already seen, so if I am looking at a story or something in a museum context or something, it would probably be quite hard for me to narrate the exposition, from A to Z.”

P26 – “I was also, I was a bit impressed at how well it works, well it’s fine.. but yeah, generally more cynical about the study, you come in and it’s generally a proof of concept or something. But you come in and it follows you, it worked quite well.”

P27 – “Another thing that delayed my movement, was the resolution of the text, I know it’s a technical issue, but it slowed me down to read the text because the resolution was a bit, I mean not that accurate.”

Researcher – “So for those who came in earlier, I think you all tended to cluster around one end of the screen. So for those who came in later is there anything that informed your behaviour or anything that influenced your behaviour as you came in?”

P22 – “Yeah, I was standing behind these two guys *P26 & P27*, tall people, so I went to the side, I was going to try and look at it from this angle, try and approach it from this degree, but it just popped up anyway. I didn’t need …”

Researcher – “So you happened to have gone …”

P22 – “Yeah, I navigated around them, and I was going to look at it from an angel, but then it came up anyway, the system detected my presence, and …”

Researcher – “And then you were ok to stand there?”

P22 – “Very happy, yeah.”

P25 – “I think people went because there was already something here, so people approach where there was already something on the display, so if you had something here, like a lure on the other screen, people would divert and go to the other screen where there was an image, so that another cluster would be built, of spectators.”

P24 – “I’d imagine that on the next trial because people know that it moves around with you, you’ll get people exploring a lot more.”

[GENERAL AGREEMENT]

Researcher – “Erm, so for those who came in first, or the first two or three or four who came in, you *P27* have already mentioned that it felt slightly uncomfortable. Did anybody else have a similar experience, of potentially knowing there was somebody looking at their screen, or …?”

P25 – "It was more of a fact for me, because I came second, there was obviously a second message, new things started popping up, and I was reading something trying to understand it and I got distracted by new things coming up and started moving, and even the pursuit of a person and when I tried to move the message skipped and I started to think, oh I'm getting lost here. This sort of effect I experienced at least."

Researcher – "So slightly overloaded?"

P25 – "Yeah, and obviously the distraction when things started appearing with new people coming in, that sort of distracted me from what I was reading, and I just wanted to check on the new thing, it sort of grabs your attention automatically pretty much, with the new things when they pop up really."

Researcher – "Can I ask, who was standing furthest to the right, of maybe the first three people. Well towards the centre, who was more central of the first three people, do you remember who that was?"

P27 – "I had that one *Middle of left screen*, so when the people pushing me, I moved a bit to the right and I think the second one came from here *to their left*."

Researcher – "So you moved more centrally."

P27 – "Yeah more centrally, away from the other, from the crowd."

Researcher – "So would you say it was away from where the people were coming to stand, or was there a, potentially something else. I noticed the screen was very open at this end *right hand side*. Erm, was it either a combination of those factors, or was it more you felt there were people behind you and you wanted to move away from that?"

P27 – "Yeah yeah, the second one. So I felt people behind me, so I just wanted to make place for the person behind me, who caused me the feeling of, err."

Researcher – "So I guess as you started to move away windows started appearing in the space you had just made, which then influenced how you *P25* ..."

P25 – "Yeah, because I was standing to the left, extreme to the left, because I just take my own space, and then other people started coming from the angle *Behind to the right* but then I read this one *own window* and something pops-up, you know around my point of when I was reading."

Researcher – "Can I just, I'll start wrapping it up because I am aware we have been talking for a while. You came in very early, I think you were *P25 - Second*, noticed there was some interactivity, and then decided to go to the very left immediately, or?"

P25 – "Yeah, because it was not really a conscious decision I would say, it's just something I do. I grabbed something and I started to read it and then I moved to the left, I don't really know why, there's not really any high level reasoning behind it I don't think. Like with many things I do … Yeah, but I moved to the left and started exploring from the angle, of like looking at the other messages, other images from the angle, yeah."

Researcher – "Ok, is there anything anyone would like to add at this point? No, ok, brilliant."

User Study 2 – Trial 4 – Transcript 2

Researcher – “Would anybody like to say what they think happened?”

P26 – “It looked like the same, but we entered differently. And, it didn’t feel, as pleasant as the first time around, at least for me. It felt like when I walked up, even the first time I walked in I walked in before last, and this time when I walked in third it was still like, where do I go, it was kind of awkward and then I almost had to trip over them and stand in the middle. And then I had to stand next to *P28* and I things *windows* clashed and it was like, which one’s mine and which one’s yours. And there was a typo in the text.”

P22 – “It was a very simple decision for me because, did you *P28* go in first, you went to the left, so I went right, and I think it had already recognised that I had started to take that path, so it just popped up. Bu then after reading it, I was just a bit like, ok I’m just standing here, so I just sort of moved to the back in case anyone wanted to step up and get closer.”

P24 – “I found myself moving away from it when it looked like there was someone standing away, compared to everyone, a couple of times with one or two people. Further back than everyone else because they didn’t have a display thing.”

P25 – “Yeah, I came in last and there was not much space for me, there was, I had to wait for somebody to move, but that was the, yeah because I came last and there was a wall of people standing here and I didn’t want to get too in to their private space. But second thing was, I think it distributed itself better, I don’t know if it was because of the entry point, or because we already talk about it and we are sort of aware in the last trial. Err, but yeah, then entry, and for me it was more intuitive and you can actually go an d stand in a place and it’s yours, rather than go in this sort of flow that was happening in the last trial that, started this thing moving. So that’s form my perspective, but I came last, so I don’t know if that influences the experience.”

P23 – “I was really irritated at some point, because obviously you need to move as people are coming in, and you know, you changing your position, and I wanted to read and if I move then obviously the box is going to follow me, but when it’s moving I lose where I am reading and it’s a bit annoying, and I just want it to be there.”

[GENERAL AGREEMENT]

P25 - ”It doesn’t have a smooth movement, it just jumps yeah.”

P24 – “Yeah I found myself exploring more how it moves across more than in the first one.”

P28 – “Yeah I think, I came in first and went to the left, I was thinking about why I went to the left, you know left to right, normal stuff. It appeared and it lead me, further to the left than I went, as it was moving across, and as you *P25* said it was a little bit jerky and that was a little bit sort of frustrating to continue to read it. Erm, and then then, *P26*, you stood next to me and interestingly I wasn’t aware of anyone else around me, I was focussing on the screen, and I was thinking where’s everyone else, I expected to feel the presence of others and I didn’t really, until ours got confused *P26*, and I didn’t particularly feel you standing next to me until ours became one, I’m not sure.”

P26 – "I don't feel we were standing close enough for that to happen. It did sort of, start doing things to each other."

P28 – "yeah, yeah, and then I became aware of you there and was kind of thinking, ok ours are interacting or getting confused, and I felt an immediate sense of competition, that I wanted to push you out of the way. And I think I actually side stepped to the right to try and push you out of the way to try and recapture mine, and with a, you know, it kind of sounds rude, but with a slight hope that you would, because I moved, that you would move out of my way a bit. So I felt a sense of, you know, needing to negotiate with other bodies in the room, to try and control what I was seeing."

P26 – "So in response to that, I was kind of, I wanted to move to the right, but I felt I didn't want to take up the right persons space as well, and then I got competitive afterwards, because I think it was you that stood next to me after that and then the things *window* jittered and then I was no longer, no longer knew who's text was this now, but it looked like it just disappeared and came back again and we were stood next to each other, and I didn't know whether this was mine or was it theirs, and it just, I tried moving a little to see if it would follow, like how you would call a dog to see if it was mine or if it was the other persons, but yeah, it was a bit weird."

P28 – "I mean, yeah, I guess it's a study situation because, after, I stood there for a while, I read the text and then I thought there's nothing much to do so I'll go somewhere else and you were, standing over at this side, and, I kind of thought I'm just going to walk in front of you, or just walk between and kind of in front of you because I want to have, you know I want to be in control almost. You know I think I found myself, if I'd been in a normal situation I wouldn't have done that , I would have stood behind you and read the stuff, but you know, I had this kind of want to, kind of push through a bit so that I had my own text that I was controlling. So what does that say about me … Not in a really strong way, but do you know what I mean."

Researcher – "Did anyone else particularly feel that notion of ownership, or wanting … [STRONG YES FROM SEVERAL PEOPLE]"

P23 – "I came in basically the last, not the last, but I basically wanted to take my position and get my own screen this time."

P25 – "The thing is, I couldn't get that you see, because I came last and there was nothing there, so I felt that I had to read the thing that is in front of someone else, but then people started moving, they started moving again. So I didn't find a space to stand, so I didn't have my own screen, my own image to see."

Researcher – "Would anyone have any idea why that might be, is it knowing how the system works or seeing other people playing with the system and you don't have one?"

P23 – "It's relative to you as a person."

P26 – "There's also the more practical aspect to, it's a two page text and there is already somebody else there reading it and you don't know if you're going to have time to start reading the first page and it's going to switch, because it's timed for the first person and not for you."

P25 – "Also, reading it from the angle, if you're at an angle it's not so comfortable."

P22 – "And also if you're sharing it seems to jitter, fluctuate between the two positions. So when you have your own, I had my own at eh beginning and I had enough time to read it, it was perfectly stationary and that was fine. The I just moved out of the way, but I saw other people kind of, fighting to get the position to read it comfortably."

P23 – "Also, you don't need to, I mean if you have your own screen then other people can't move it, so it's your …"

Researcher – "So has anyone particularly noticed anything about the interaction of windows, so you have you r window and someone else's window, and you mention they flicker and people are fighting over them and they merge, or … ?"

P25 – "Two of them went on top of each other I think in the middle, I saw in the corner of my eye, I found that sort of peculiar."

P26 – "Mine and *P28* were kind of shaking next to each other, almost. Almost made me feel like we were standing too close so I tried to move away. In my mind it's just kind of odd that the sensors can't tell if we're one person or two and it's twitching, or if the system is just designed to tell people you're standing too close, move apart. It could be one, or …."

P28 – "I did wonder early on, as we were, as I was early in, whether or not, I might be completely wrong, if they were all trying to move people to the left, or if they were trying to move people apart. So as I was trying to walk up to their, I don't know who came in next, I wasn't looking, but as I came in there was a deliberate trying to spread apart."

P22 – "Yeah, I came in next and I got the impression it was trying to move us apart, but as I came in I did deliberately made that decision to go right, because I didn't want to stack up behind you. I don't know if that was prompted because it was quite and instantaneous thing, so. I don't know exactly what moment it popped up and sent me that way, so."

P28 – "Whether it was following you or you were following it."

P22 – "Yeah, chicken and the egg."

P25 – "It's reading your mind."

P24 – "It seems like it works best when there's six squares on the screen, so it seems like there's always one person who has to move around, or, erm, try and get in somewhere. It might just be how the sensors are or it might be deliberate."

P26 – "Probably why you need seven people."

P25 – "It's kind of like a chairs game, that you only have one chair less than people."

P27 – "Another think which, I think, caused this density, is the size of the font, so if you have a bit bigger font I think, I think there will be more space. I mean, you can stay a bit more in the room instead of go too close to the screen. I mean I kind of, I struggle to read the text from here, so I have to come a bit closer, perhaps one or two meters."

Researcher – "Ok so, erm, we'll stick a pin in that, that's factors of presentation. This has been quite carefully designed to work exactly this way and encourage certain distances from the display for exactly this reason, you know, it's such a powerful mechanism, and simplifying this down as much as possible, just to get a sense of how you guys feel about it, how you can learn from it basically and what you can learn from one another. Potentially just cycle back round to, those that had screen that interacted, how did you feel that your physical position both to the screen and to one another, potentially had an effect upon what you then saw, what then happened, is there anything that might jump out at the moment?"

P26 – "I didn't feel much in control at that point, when it started doing things that I didn't understand. I tried moving forwards and backwards to try and regain control, but nothing seemed to appease it, so I stopped trying. And then *P28* walked away and it kind of calmed down."

Researcher – "Ok, and just the final point would be, how do you feel there was, if there was any difference in entering from the first trial and entering from the second trial. You've already covered quite a lot of this, but if there's anything that's quite strongly in your mind now that we've covered quite a lot of these points."

P25 – "I think the distribution was better, people immediately went left right and centre instead of accumulating in one side, like they was on the first trial. But like I say, I don't know whether it was because there was a different entry or because we just discussed that in a different trial."

P24 – "I think with the different entry you can kind of watch what people do when they go out."

P22 – "For me, I thought being one of the early people coming in, more aware of the people coming behind me and the people standing behind me. I'm not quite sure, but I was about middle first time and, then it just felt like everybody would go round each other and just stack up, line up, whereas this time it felt that the stream of people coming in made me more aware that there was definitely going to be more people coming in behind me, so I should just get out of the way as soon as possible. If that makes sense."

Researcher – "Did that particularly change your behaviour do you think, between the two trials?"

P22 – "Yeah, because in the first on I would just stand there happily and read it, whereas this time, maybe I'm just getting better at reading it, this time err. Yeah, this time as soon as I'd read it I felt like I had this obligation to move out of the way, and also I was just a bit bored of standing there."

P27 – "I think also there is a surprise effect, so once you come in you don't see anything, and once you are about here *One meter in to the space* you see a text box, and you just, you stay instantly. And since you can read the text from there you are just reading it. But from here *Second entry point* you just see something happening, you see there is a text, but you can't read it and that motivates you to come closer to the screen."

Researcher – "Do you think there is maybe anything in, form this entry position, you can already see the text and you know how the system is working, you know you could have your own window."

P27 – "Yeah, if you are not already directly in front of the text, in front of the screen, if you have a slight angle you see the text is moving with you and that motivates you to move on, and to interact with it."

P24 – "I think the thing as well, always things with a first trial is things are a bit awkward, you see what other people do and you've never seen it before."

P25 – “You don’t know what to expect.”

P24 – “People start looking at you funny.”

P26 – “I thought the distribution in the first trial, I don’t know if it’s better, I don’t know if we were all very close to each other, but I think it’s more efficient because people were basically lining up and getting their own screen. As opposed to the second one where it’s not, there were two or, I was the third and I couldn’t immediately find where I could stand. Because I guess when you are walking this way, as soon as there’s enough space for your *window*, it pops up, where as this one, the first two and they pop up and suddenly there’s not really an obvious space to go after.”

Researcher – “So just, final final, those who were standing at the display, with potentially an awareness that there are people around them, or that there are maybe conflict between the windows. How do you think that yo maybe approached the resolution of that, do you think it would maybe be through what you could see on the display or through an awareness of where others were, or do you think it was maybe a more personal decision that this wasn’t working, and … ? It’s ok if there’s nothing in there for the time being, that’s not a problem.”

P28 – “I think for me as I said before, I was surprisingly unaware of where other people were, I didn’t look around at all. It took me a while to realise. So I didn’t particularly feel the need to resolve anything, until we had the clash between *P26* and I’s one.”

P26 – “yeah, I didn’t get whether that clash was, was er, jitter in the system and whether it was something happening and whether I was supposed to address or not, and if not I didn’t know how, and even also for the second case when I clashed I didn’t know who’s screen that was anymore, and at that point there was no kind of direct easily accessible feedback I could get, to say, oh this is what’s happening, it’s just, this is the situation and you figure it out on your own, this is, if you should move or not. At no point there was no, oh I need to do this to resolve this issue, it wasn’t clear to me.”

Researcher – “Was there anything in the relationship of the screen layout, your physical position and the physical relationship of your position to the positions of others in how your experience with the content window played and how did any of these factors influence your decision making?”

P28 – “I didn’t quite know what the problem was or how to resolve it, so I think what I ended up doing was, I think oh I’m just going to leave and go elsewhere and see what happens next, what happens somewhere else and see if I can get my own think again in a different place, because it wasn’t obvious what to do about the problem, other than to be shuffled about a little bit. It didn’t really seem to do anything, I didn’t really understand what to do about it. So my mechanism was to just leave. I went over to the opposite side.”

P23 – “I guess this depends on the number of these windows you have, I just don’t understand on how you decide how many to have. Do you just decide on the number of the cluster of people, or the number of people.”

Researcher – “So I don’t know how much I can really explain about the system, it’s fine I can explain it, it’s just ai haven’t really figured out how much I can explain and how this then influences your behaviour yet. Basically anyone that’s standing in front of this display gets a window, however, there are mechanisms that I am exploring as well, so you know, it’s all kind of been set up to work at this distance and work in certain manners and the next trial is going to be an exploration of how these windows interact with one another. So the way you interact and understand this system is really interesting."

User Study 2 – Trial 4 – Transcript 3

Researcher – "ok, so I'll ask the same question again, would anyone like to say what they think happened that time?"

P22 – "I should go first, erm, I consciously made a decision to go to the right, and I felt like it was trying to draw be back to the left, and, it seemed very adaptive and it stuck me right there. Then I finished reading and then I left."

P26 – "So you missed the cool bit then."

P22 - "What was the cool bit."

P26 – "The cool bit was you got your own box even if we're not at the front and it goes behind the others."

P22 – "Ah no, I didn't see that."

P26 – "So, there's someone there and I go behind him, I get my screen first and then it kind of fades to go behind him and goes back in the front, which was kind of cool. So you can still see your screen even if you're not there. And it tells you, oh you're standing behind this guy and you can go over to the right and you can still see, and it worked quite well for me."

P24 – "Towards the end I found myself moving more towards people, because I wanted to see what happened."

P27 – "I found that last one quite bad, the thing was it was a bit fast, so you had to come closer to the screen. And yeah, at one time you took down my text. I saw the text box move to the left to pass behind, so erm, I tried to get the screen back, but by the end I had my box again, so at one point it stood there, so it didn't move. So basically it took me from there to a certain point, but I can, err, but I stood and I could read the text."

P25 – "For me it felt slightly more responsive, like the sensitivity of the movement was slightly better, so the jumps were slightly smaller and it sort of felt like it really follows me now and I have more control over what I am looking at, even though I haven't moved much, just a little and it felt it really nicely followed me."

P28 – "Yeah I felt the same."

P23 – "Yeah, so I really didn't like it, because I was standing there and I wasn't moving and I don't know if it was like a bug or something, and it's just becoming smaller and bigger and smaller and bigger, so I couldn't read anything. And now you *P27* came in in front of me and that completely demotivated me, so I just left."

Researcher – "Yeah, I saw that, you did exactly this *exasperated gesture* and just left."

P26 – "I'm the only one that liked it then I guess. I thought, I don't know, I thought that I kind of wanted to stand in front of someone to see if that pushes them back, but I didn't do that."

Researcher – "is there a particular reason you didn't?"

P26 – “Well because it doesn’t seem like a nice thing to do when someone is trying to read something. Yeah, the idea that my, that it tells you that, I can see you, but you can’t read unless you find somewhere better, I found that quite useful.”

P28 – “I think I followed you *P22* in, and like you I think I had already made a decision to go to that far side, in a let’s try and give everyone space kind of way, and I think I very much mirrored and followed you *P22* in. So I started off reading yours as it was following in and mine popped up, and I had this odd sensation where, even though I’m going to continue to walk over to this side, it was following me, and it was moving to the right, it was also drawing me in as well. I wanted to walk forward more than I would have, more than I intended to do. So there was that, and as soon as you *P22* left, IO followed that cue and I left as well.”

Researcher – “Would you say your, was that your proximity to the screen or would you say the depth from the entry point to where you ended up, and do you think you might have a particular reason why that might be?”

P28 – “I don’t know, I almost felt it was, yeah, it was the briefest of thoughts, but I almost felt like it was, I was intended, and I was like, I’m going to walk over and I’m going to stand next to you, over to this side, and it, it popped up and I looked over at it following you, and I had the briefest sensation that I wanted to walk towards it.”

Researcher – “And that would be towards the actual display in terms of proximity, or towards where someone else was?”

P28 – “Towards the actual display, to the box, not the display, but the projection.”

Researcher – “And you felt the box was following you or you were following it?”

P28 – “I was following it.”

P27 – “Yeah, that happened to me as well.”

Researcher – “Is there anyone else who had a similar feeling?”

P26 – “No not really.”

P25 – “yeah, I started in one place, but I did not feel that it was dragging me. Apart from a little jitter, but I think it just picked another person when they were coming through and it slightly moved, but it just adjusted, but it wasn’t really dragging me anywhere.”

P28 – “But can I add to that, that was when I was walking in, and that was when yours *P22* was doing the same thing, because you were walking over, so I could see your box moving that way, mone appeared and started moving that way, so there was sense of motion already set up, from the both of them. But as soon as I was stationary and I was moving around, the sense then was that I was controlling it. So it was just that initial walking in to it that I felt I was following it.”

P22 – “yeah, so from my perspective it was definitely a conscious decision to take that path and see if it would follow me, so I don’t know if that influenced *P28* behaviour, but yeah. I didn’t feel like it was controlling me at all.”

Researcher – “Do you feel that potentially, the relationship of the box to, to *P22* and there’s this pairing, is there something in there perhaps.”

P28 – "Yeah, er I think so, because, the first box that I saw *P22* was moving that direction, I guess I'm not really thinking is *P22* following the box or is the box following *P22*, it's just that motion that I'm seeing is already set in motion from the person before me, and mine starts doing it and I know that mine's following me, but it did have that sense that everything was being led, guided to that side because of the person before me."

P22 – "Like I said, I was very satisfied that you had followed the same line and that it had worked out, because I couldn't really see what was going on out of my periphery on this side *right*, but at least for us two it seemed to work very well and we were both like, stationary, we had time to read it and then move on. So as a pairing it seemed to work very well."

Researcher – "Do you particularly have any reasoning for why you made that decision to be all the way over in the corner?"

P22 – "Yeah, because the first time we were, we came in this way so I wanted to try and go this way. It was, I was trying to test the system."

P28 – "I kind of thought as we left, I kind of thought, ok we're, we've spoken lot about being in people's way and that kind of ordering of ourselves. And I kind of looked to the side and we were all in a kind of nice organised kind of line, so I had that feeling of, ok we're behaving in response to our discussions now."

P22 – "Yeah, I would agree with that, I felt like I was just trying to play suit and just make it easy for everybody, by getting in a line. So yeah, that influenced it as well."

P24 – "I think the thing I noticed about being last was that, erm, more space than last time, so I remember you *P25* saying there was hardly any, whereas this time I thought there was enough space. You know, the box appeared, there were none of the issues that appeared last trial."

Researcher – "So potentially a group wide question. Knowing that there is a line of people coming in and that you have now done three trials, is that having an influence on what you then do or how you use the system, or … ?"

P27 – "Yeah, it's controlling you so, in the first two trials you have to control *your position*, but in this trial you are controlled a bit by the system and position yourself in the room. So …"

Researcher – "So for this instance if you were in a museum or gallery content and it was yourself or maybe one or two other people you were with, but not a large number. So for instance seven people can comfortably span the distance of this display, erm, if it was just several people, or one or two others, or no one here, or one or two after you, would your behaviour be, would you think the organisation would be there, the need to organise yourselves, or?"

P23 – "I think definitely the need to control the distance, so when I felt there was something I need to control I come closer, whereas the first time I came in I was standing at the back I was completely happy with that, because there was only one screen for our little cluster, so."

P26 – "I think when you are one of the first to get in, you want to take up as little space as possible, when you are last to get in you just want to find space, you just want to find any space you can get to use. I think that's kind of the decision making process."

P25 – “Yeah, I agree.”

Researcher – “Ok, so something I’m picking up on a few people are talking about. If you maybe think about the interactions between the screens that you are seeing and where you physically stand and where those around you are physically standing, you mentioning, you know, your sense of control, you *P23* mentioned you want more control so you are moving closer. Are people picking up on these kinds of spatial relationship, these kinds of socio-spatial relationships and what then happens, and what then happens when you interact with one another?”

P25 – “Mmm, maybe not verbatim, but this idea that, that you *P26* mentioned that the text sort of goes behind, sort of fades out a bit, that might sort of be, I don’t know whether that’s social or whether you will find a comfort so that you will move. I mean for me for example, just looking at the people, I didn’t really care where people are, I just stood in a corner and I am just focussing on what I am reading, and I had no interest where other people are, what so ever. But I was aware that there were some things that were changing on the screen, but, yeah I didn’t look around. Maybe because I came in the middle and I had no space to find space, you know issues when I came in.”

Researcher – “So those things that were happening on the screen, did that have any particular influence on, or you were just, you were aware of it?”

P25 – “I was aware of it, it was interesting, but didn’t really influence me in a way. I was just in a corner here where I usually come, because that’s where I like to, you know stand near here. Yeah, I was seeing thing happen, but I had no issues.”

P26 – “It felt more like a practical guide to where you should stand, other than a social queue to what you are doing. You know, when it is just faded but next to another person, I was like, oh ok, I’m still not far enough, but it didn’t feel like, oh it’s telling me I’m invading someone’s space because I’m not, I was standing behind them, at a fair distance too, it wasn’t like that. It was like, oh you need to move to the right, oh you need to move to the left and not need to stop being in peoples space.”

P28 – “But it’s through what you see on the screen rather than what you see in physical position relative to other people.”

P26 – “I mean my position was something, I guess is implicit in what I, I’m not actively observing it, I can sense when I’m too close to someone. But I’m watching this and it tells me, it doesn’t tell you you are too close to someone, it tells you your screen is in a, not a good place to view it so move somewhere else.”

P25 – “Well I was more aware of what happens on the screen than what happens on the floor as such.”

P23 – “I think it was the other way around, like, usually when I’m in a gallery ai am always spending time calculating my distance to other people, because I hate other people intruding my personal space. So, in this case, when I first came in and the screen was kind of stable, I calculated my distance and I was fine I could focus on the reading, whereas last time it was like, oh, it’s too complicated I’m going to leave.”

Researcher – "So for those who had a solid screen, not necessarily the entire time, but had a solid screen and were aware of other screen s doing this animation, how were you aware of that, what did it maybe make you think, or did it have an effect on what you did."

P27 – "For me, not. So I was just focussing on the text, so I had a feeling I was a bit slow, so it switched to the second page and I couldn't read the entire text on the first page."

P25 – "I was aware of it, it was interesting, it made it look more responsive and more engaging. But I first thought it disappeared because someone had left, so that it fade. But yeah, I didn't know that it was actually somebody in front of somebody, or that walking in front of each other."

P28 – "I noticed it but I didn't understand what was going on, but I don't think I changed places, so I didn't trigger it myself. But I think when we walked in, I think yours *P22* briefly went from solid to greyed out and solid again, so I think I first noticed in when I was walking in."

P22 – "I can't say I noticed it."

P28 – "And I thought, what's that, and there, I think that kind of set up my, it's some bug or something, so I didn't' really pay much attention to it."

P26 – "Yeah, you guys walked in in a way that wouldn't necessarily trigger it, because you just did that. And it would work for someone who just went like this *walks behind*. For me I saw it when I was, first with the two people who came in before me and I saw it happen, then I tried my own an di was like, oh this works actually, but then it never happened that I saw someone else's screen go behind mine, so I never felt like I have to go somewhere or something, but I never saw that so I never felt like I had to do that."

Researcher – "Did it introduce this idea, potentially knowing that there is someone else behind you, was that possibly because you saw this animation in the second row of people and you saw it happen, or?"

P26 – "Well I just walked in and I saw mine do that, and as soon as I found a place, a comfortable place for me to read my thing, I never saw it happen to me, in terms of someone else do that. Because I think I was one of the last person, so."

Researcher – "Does anyone have anything they would lie to add at this point? No, ok."

User Study 2 – Trial 4 – Transcript 4

Researcher – "Would anyone like to say what they think happened?"

P26 – "It felt like the same as last time but better, I don't know how it was better, but it felt better. It was much smoother, it was worse for you *P22*."

P22 – "yeah I came in last."

P27 – "I think the problem was trying to find a place where I can get my screen first. Because the five people, they lined up very equally, so I had to squeeze in to the screen, or in to the screen to get my box, and from that point it was then very smooth. So at the point, after a couple of seconds I figured out that I can move around and the box with fade out slightly, but I know still the place and I know that it will move at me, and once I go closer to the screen and it will be more bright and I can read again."

P24 – "the issue I had was when people moved close to me it faded out. When I was near the bottom of the first or second page, it didn't display the bottom of the page which meant I couldn't read what was going on. That would be rather brief because people then tended to move away again, or move around, start exploring. But you get sort of these flash points where you're reading but then you can't do it anymore."

Researcher – "Did you find it was a particular, when you got your window back, was it a problem or was it just the inconvenience?"

P24 – "Not really, it was just for a brief time it was, I had to stop and wait for someone to get lost."

P25 – "I think people started being a bit more experimental with how they move and what they do and what happens. So it was a bit mixed with experience and experiences of somebody else experimenting, so I was slightly more aware of people, where they are, on the floor rather than on the screen, but that's probably because there was slightly more movement this time around. Other than this it was the same as the one before."

P27 – "I agree as well, so this time it was, maybe the first time that I have experimented around. In the first three trials I just try and go to the screen and just try and take information out of it and I didn't try and experiment with it so much."

Researcher – "Is there anything else that really jumped out, or?"

P28 – "The boxes starting at the bottom of the screen and kind of scrolling up, I kind of thought what's the point of that, I don't think it particularly added anything to the interaction, I think it was better when it came in at the height that it sits at. I think it's as you guys have said, I was one of the people that decided to walk backwards and forwards, because I hadn't really experience the box going behind others, and that worked quite nicely. There was moment where I saw one come under the one next to me and under mine and under the next one and that prompted me to turn around, and it was you *26* leaving the space."

P26 – "I felt bad about that, because I went all the way to the right and I wanted to leave, and the tracking was good enough that it tracked me all the way out, and I was just disrupting everyone's box."

P28 – "I think that was quite interesting because up until that point, I think I had been quite unaware of other people's positions in the room, and that made me more aware of other people's positions. However, when we all started moving around, tat quite quickly got quite irritating."

P22 – "That was about the time that I came in I think. So as soon as I'd found a spot, I had to squeeze in on the right hand side, and I think it just got a bit busy over there, and it was fading in and out and it was spuriously moving on the screen. It made it really difficult for me to read it that time."

P25 - "From my personal perspective I found the, the last two trials in comparison with the first two, the last two ones were a bit more busy, there was so much popping up, there was stuff getting blurred, that was actually quite helpful. The display was already quite busy, and there was no, you know you don't have the black stuff around yourself, and then something white pops out and grabs your attentions. So I felt much less distracted when we had the, the fading stuff, the fading effect implemented."

P22 – "I would say conversely, compared to the first time, it did seems to recognise me and fix me at a good equal distance to the two people flanking me, but it just, it just wasn't stable in that position."

P25 – "Or maybe you started learning the system better, realise how to play it, how to control it better."

P22 – "Yeah perhaps, because I didn't, I consciously didn't go behind anybody. So I did try to get in line, but erm, you know, it stayed like, around the positon, but it was flickering."

Researcher – "Did you notice any response from the people to the side of you? So in particular, you have already mentioned you came in quite late and there were five people already there and quite equally space, and not enough space for you to have your own window, and your window was then animated, it was greyed out. And then you are now mentioning you came in last *P22 – Yeah last*. And had a very similar situation where you had space and you window was then responding strangely, did you notice this encourage or elicited any kind of response from those people next to you. For any of those people who might be around the table …"

P22 – "not really that I noticed."

P27 – "Proabbly that I had the feeling that I, how was it, I think I went between *P26 & P28* and they moved slightly to the right and left. So they make also space to me, I don't know if you *P26 & P28* noticed that but … once I came they moved slightly to the left and right."

P22 – "Yeah, I think that similarly they might have just opened up a little bit."

P27 – "I think the first thing that I noticed was that the spacing was so equally, so I mean from here it is, I am not sure if each one is staying with the other one. So as a person coming in you have to try and choice where you want to go in."

Researcher – "And do you think that's particularly a point of the entry position?"

P27 – "mmm, yeah."

Researcher – "So as mentioned the two key variables are the entry position and the window interactions, so anything that you notice about how this affect your interaction or experience is really helpful to me."

P24 – "I think the interesting one was the third group, because the third group was coming in from the side and after all the clashing stuff, it seemed that everyone organised themselves in quite a spaced out fashion, so it seemed that everyone got a window. Whereas with the fourth one people had seen that they overlap and what have you, people seemed to experiment a bit more and moved around from different bits. In one of the situations people got quite coordinated and spaced out again, which I thought was quite interesting."

P28 – "I think I was going to say a similar thing. I think the latter two seemed a bit better, apart from the final one where we started experimenting, but there was moment where people seemed quite organised and then people started moving around. So I think there was a definite learning thing, where in the first two people were kind of walking up and not really thinking about it.”

P26 – “I found it quite interesting where, like for the last one, I thought that was the best and *P22* thought it was the worst. We both experienced the same thing, but, one of us had a completely different identity to it. I wonder if it’s just a thing of who goes in first.”

P22 – “Were you first on that one.”

P26 – “I was second, but the one in front of me went left and I went right, it was an easy decision. I stood as for to the right as possible so my screen was right at the edge, and I don’t even have to worry anymore because I can’t do better than this. So I saw my thing and then I walked away, but I was watching other people while I was doing it and I saw that everything seemed to work quite well, all the tracking seemed to be quite stable and all that other stuff, an di thought, you know, I walked out thinking that was a very good experience, completely oblivious to the fact that other people hated it, just because they walked in later or something.”

P22 – “Yeah in comparison to when I walked in first, it was totally contrasting experience.”

P27 – “Yeah I think there is a correlation to the time when you come in and the time to get your screen. I mean to more time you spend to get your screen, the, the more, or the more difficult, or the less pleasant it is to you to interact with the system. So if you come first and you get your screen then you have a nice feeling, but if you come maybe as the sixth person or maybe as the last person, you have to look around a bit to get your screen, and I think the time is, yeah, once it is more it feels less.”

P28 – “part of that I agree, part of the difficultly is that you are having to try and negotiate a physical space, but also when a screen does pop up, you are also kind of, interact, you are almost kind of trying to interact with two things and trying to negotiate both of them. You are trying to rad the thing because you are still trying to find the best physical position, and it gets in the way of your experience, it’s not just trying to find a space but trying to interact smoothly with what’s going on at the same time.“

P26 – “I don’t think that it’s a, I don’t think it’s a comment about the system, I think it’s more a comment about the study. The text that we were reading, I didn’t care much about anyway, so when I couldn’t read it I didn’t really care anyway, I just wanted to get my own box how easy is it to secure my own box and am I bothering anybody else. Once I’ve got those three down then I didn’t; care what the text was, if I can read it that’s fine, but if I can’t then I’ll just walk away, but if I was in a museum and I was paying money to go and see these things I would want to read all the stuff, and I couldn’t for some reason that would be quite a problem.”

P25 – “Yeah, the quality of the stimuli kind of crossed my mind because it’s quite hard to kind of put yourself in let’s say a gallery position that you try to experinec ea certain piece of art and you have a driving engagement, but here to do it you have a sort of, yeah, I had the primal reasons of, I sort of want my own box, or … or em, yeah. The stimuli lacked the quality you would expect of being quite engaging, or captivating in its essence.”

P27 – “my priority was always in to read the text first in the aim to get more information in how to use the system, so it was not always initially obvious in how to use the system, so I get to, I try to read the text first to get out more.”

P28 – “I don’t think I read the text on the last two, and I think I half read it on the second one. I t was only on the first one that I really too notice of it.”

P24 – “I hadn’t read the first on, to contrast actually.”

P27 – “The only one I didn’t read was the last one. Ion the first three I always tried to read it. In the fourth one I thought it was better to actually try it out *the window interaction* and see how it works.”

P24 – “there was a typo in the last one as well, at the very end of it.”

P24 – “One thing I noticed in the second half of the experiment was, I’m not sure if it was because of the different type of transition, was the thing kept crashing, was that I spent less time on it overall. So I was likely to leave slightly earlier.”

P22 – “I don’t think I was consciously aware of it while I was doing it, but there was this urge to read it as quickly as possible in case the system crashed. Which I know is just a comment on the experimental.”

P25 – “It didn’t matter to me that the system crashed.”

P22 – “yeah, it didn’t matter that it crashed, and I think that then, I think I wasn’t thinking about it, but in the fourth one I think ojk I’ve got to get in there and read this now. Because retrospectively I might have waited until everyone had moved on and waited until a position was free. That might just be a comment about the nature of the experiment and the equipment limitations.”

Researcher – “Do you think that if you had been earlier and you had been one of the first three or five people you might have just gone in there are read the content, or because you were the last you had this feeling that I may actually just wait, but then there was this driving factor that the system might just crash at any moment?”

P22 – “well, I didn’t think that at the time but now, looking back, I might have been more patient in the previous tests if there hadn’t been that system crash.”

Researcher – “Would you have potentially still tried to engage with the system if, particularly the second set of trials where there is an animation between the content *windows*, and you’ve picked up on, oh this is tracking me, I’m aware it’s found me, but I’m not in a position where I can read, do you think you may have still tried to engage with the system?”

P22 – “Well I think it engaged with me before I did with it actually, in the final one, like on approaching the line of people and finding my position in it, it had already came up with this faded grey box that had come up between the two. But yeah there was that impetus to get in there and read it because there was that danger that it might just explode at any point.”

User study 2 – Audio Analysis – Abstract

<u>Personal Interaction Preference - Constellations</u>

User preferred to have their own window as they could interact in their own manner. Users do not want to interrupt or be interrupted during their personal interaction. [P2]

- There is a preference for an immediate interaction if possible.
- Social and physical cues will influence how and where users can engage – otherwise users will queue – queuing may result in the user disengaging
- Users do not like to have a queue form and applied social pressure
- System learning to support individual interactions would be preferred if a user can have their own display

Personal preference for space and area or nature of the interaction will have a significant factor on how a user engage with the system. Lack of awareness or confusion about the system response will impact upon these decision. [P1]

Entry Social and Physical limitations

Ordering of entry would affect who was already there. The social – physical limitations would affect how and where to engage. Having the mapping allowed for easy correction – Sharing / negotiation. [P7].

- Lack of understanding and physical arrangement will support natural interaction "Honey Pot Effect"
- Mapping supports the negotiation and sharing of the space
- A lack of awareness or knowledge will not support sharing or negotiation – it falls back to personal social space and pressure

Mapping content to users

The mapping of content to a single users behaviour increases the awareness of ownership and simplifies the interaction and content search. There is still confusion caused by multiple users, however, this introduces a new social awareness which encourages negotiation and sharing. [P5]

- Mapping improves social awareness and encourages negotiation and sharing
- Lack of understanding about the mapping reduces the focus on a single window
- Mapping simplifies the content search when there is not an overload of information

Social Awareness

Users gain a greater social awareness of one another through viewing mapped content on the display [P5]

- Having a greater awareness of other users is a nice addition to spatial behaviour
- Seeing another users content on the display introduces a social pressure about position and potential violations of personal space

User enter and are aware of the current social layout as well as their own characteristics [P1]

- Constellations of users will influence how to approach and interact
- An awareness of personal space and physical interaction will influence how and where a user stands – tall users will stand further back.

A social awareness helps to paint a picture of the scene with additional learning – there are factors of how beneficial this is. [P7]

- It is nice to have this as long as it is not overwhelming
- Proximity to the display may support better feedback to users based on window interaction.

There is an awareness of social conventions and normal behaviours. The awareness of the system and interaction between separate users can reduce the potential for certain actions – Shoulder surfing. [P1&6]

- The display awareness of others without a physical awareness can impact both users
- Knowing there is someone there but not seeing them can make users uncomfortable
- Knowing you can be seen by another users and impacting upon them introduces a new social pressure back to the users standing behind – Shoulder surfing

Physical behaviours are encouraged by the knowledge of the digital violation. [P1]

- The user knew there would be an interaction between the windows and not just a physical blocking of line of sight

This encouraged a more performative behaviour to make an allowance for the action

System Learning

Learning about the system functionality changes how users are likely to approach and interact [P1&2]

- With limited knowledge of the system then users will follow "Honey Pot Effect", either moving towards other groups or content
- Without knowledge of mappings or system function there is frustration at the mapping of content to other users
- If there is no feedback of why the configuration is changing this separates the users expectations to intentions of use or interaction

A lack of knowledge of the system function and feedback to users results in a poor experience as there is confusion about the interaction and overload of the information shown. Clear ownership and feedback would reduce this issue. [P1&3].

- Without relation of multiple content to a single user or feedback about the interactions or ownership there is overload and distraction
- It is not clear what to relate or engage with

Too many users in the space reduces the awareness of the mapping and introduces confusion between the window interactions. [P5]

- Density of users limits the awareness of the system mapping and feedback about current interactions.
- Overloaded information and content window interactions presents confusion without clear feedback about ownership and social behaviour.

The level of system learning can be used and related to the social and physical use of space. Users do not want to overload or impact upon others. While there are known social conventions to interact, the system function introduces uncertainty about the nature of the interaction for others. [P3]

- There are social conventions that are understood and maintained.
- The function of the system can introduce uncertainty to other users experience if the system response is not well understood or unpredictable
- As the system response become better understood there is an added social awareness of distracting others by interacting
- The nature of the mappings is known to cause a digital violation to others even when the users is making no physical violation
- Users want to explore the system, however, there is an awareness that this will cause an issue to others

Presentation

Multiple duplications and moving content is distracting to users without clear feedback [P3]

- Moving content is distracting to users in their peripheral vision
- Without clear indication of what to engage with users will maintain an awareness of multiple pieces of content and reduce their own focus

Feedback

Without clear feedback or understanding of the system function there is an overload of content and a reduced awareness of the mapping. [P5]

- As more users enter the space there is a limited awareness of what the interactions mean or how they relate to a single user
- Either awareness of the system or feedback is required to support a users interaction
- It takes time and exploration to understand the nature of the interaction – without this time there is overload
- The interaction introduces a social pressure to users without clear feedback or time to establish the nature of the mapping

A social awareness helps to paint a picture of the scene with additional learning – there are factors of how beneficial this is. [P7]

- It is nice to have this as long as it is not overwhelming
- Proximity to the display may support better feedback to users based on window interaction.

Window Interaction

The animation provides a good feedback to users and prevents flickering and distraction. [P2]

- Presenting clear feedback to users makes for a better understanding of the system function
- There is a wider awareness of the need to move to re-establish the windows position

- Loss of the window is unclear as to why
- Without clear ownership of the window it is hard to re-establish the interaction

Any uncertainty in the interaction about losing the window or pressure from new users reduced the experience. [P5]

- New users entering the space would cause an uncomfortable social interaction and reduce the likelihood of staying
- Flickering of the window or other windows nearby would be distracting and cause uncertainty.
- Interaction between windows (flickering / animation) would inform towards another user – this could either cause movement / negotiation, or uncertainty depending on the ordering.

The mapping of content and social awareness would cause movement and negotiation in a way that would not take place with static content. [P5]

- Flickering or animation would cause distraction but would also raise awareness of another user
- With static content there is an inter-personal battle to maintain a good viewing location / the quality of the interaction
- This system supported an awareness and a method to correct the position for negotiation

The window interactions show users more information about their environment through digital awareness – this awareness can introduce uncertainty about the nature of the physical awareness (where is the other person). Knowing you can be seen through the mapping places pressure on to other users. [P1&6]

- If the mapping feedback is not sufficient to inform the users about the actual behaviour of others this will cause uncertainty in the interaction
- Introducing uncertainty to another user will reduce your interaction or behaviours
- The nature of the mapping and how this feeds back to others can influence your behaviour

Appendix E – Adaptive Study Results

E1 Transcripts

N.B. Due to loss of data the majority of the transcripts have been lost for this trial. The Audio and Video are still held on a secure drive and the work can be replicated if the evidence is required.

Study 3 Trial 2 – Transcript 1 (Short)

Going last – looking for a space – I went in and it seemed something responded to me as I got close to the screen. I wasn't that close – It seemed like it tracked me from pretty far.

- Content was placed in the space that the user had already selected to go to – There was clear line of sight to the location and it appeared to pre-empty the approach.

Forced decision for where to stand – identified a gap and went there.

Fifth person entering – it seemed like it was trying to put me next to the four people cluster. When another person entered I was pushed to the side – At the same time the content changed (colour remained the same) so was not sure if I was supposed to stay with my colour or with my story.

- There was no colour change only story change – slightly annoying as the story hadn't changed.

Sixth user – the screen was flickering – Am I too short – Wondering why the window was flickering – Tried moving to get the window to stay solid again. Went in to the last space – adaptation caused the right hand person to move – this seemed strange as there was already a space to go to. Following the person in before them – it seemed like this was the person to stand next to as they had come in in order. It seemed strange that the new content window was produced in front of new user – the adaptation forced the on-going user to move – this was not understood as there was already space there.

- There is a queueing effect with new people coming in – it seems like they should cluster or use the same space as they are entering the space separately from those already there.

Flashing and adaptation were still noticeable from the far left of the display – distracting. Wouldn't have expected it to be so prominent, but bright flashing was annoying.

The content was quite demanding, so having a lot of changes without a clear distinction about the order of interaction made it difficult to understand the experience.

Users standing next to one another had the same colour. This was confusing to identify who was who when there were higher numbers of users in the space – movement is not easy to test tracking.

Study 3 Trial 2 – Transcript 2 (Short)

The system tried to move me to make space for somebody else and it was very annoying.

There are two problems with engaging with the content; It is moving so you have to keep tracking of it while still reading content, and there is a timer on that content. So it is a lose-lose situation when trying to engage with the content. It was an annoying thing.

- Movement can happen as pages change – movement happens because of someone else so there is a lot going on and it is hard to carry out the task. There can also be other windows which are moving, which are distracting and make you want to look.

When there was a moving window behind mine it appeared there was someone behind me.

Windows appeared in an available slot. There were already windows on the display and people in the space. There were physical constraints of the others using the display so I went to a rough area. As I got near a window appeared.

I went to a gap, based on where people were. As I got nearby a window appeared in the space and it was easy for me to get to it. I don’t feel like I was guided.

I wanted to go to the end but then a window appeared in the middle so I had to stand there. Then as things changed I was slowly pushed to the end, where I wanted to be anyway. It was annoying because it kept moving and disturbing those who were already reading.

Interaction between windows caused a user to adjust to allow a full window to come to size. The adaptation had already pushed me to the right – it was hard to tell why because I was focussing on my window. I could see there was another person struggling to get a window, so I moved back (after the adaptation) to make room for somebody else who had stood there.

Moved to an end of the display to anchor the window and allow as much space as possible for more users.

There were quite a few spaces around me – There was not much effect to my window but I had to move to allow other people in. I think someone was stuck over the join in the display so I decided to move to make room for others.

I was reading and it moved so I had to move to continue reading – It depends how much it happens. If it happens once then it would probably be fine, but because there were lots of people coming in quickly I think I would get annoyed. I couldn’t see why it moved, but I could understand why because of other users. The second time when I chose to move it was obvious because I could see there was another user there who couldn’t get a full window.

- I’d prefer to leave it to the user to make their own space because I am a considerate person, but also I have been in situations where I want someone to be shoved out of the way. I think it is very context dependant.

Want minimal interaction between windows. Once I have a window at the display, I don’t want other windows to interact with it. There was lots of flickering and it was annoying.

Study 3 Trial 2 – Transcript 3 (Short)

When new people came in we were all moved to the right – when we first moved it was a bit of a shock because I couldn't see new people coming in. I was moved directly to the end and then I could just stay there, so it worked better.

People were coming in and slotting in to the right, so I was never able to catch up with my original window. Someone had moved in and taken my slot with my window. So I took a new window with a different colour, which happened to have the same content that I had before, but I couldn't get my one back.

- If the content was most important to whether I had wanted to get my window back. I wouldn't know where I was anymore.

There was still a lot of tracking going on at the left end of the display. It was all fine, then everything moved across for no reason. Then after some messing around I got another window. It was a bit of a nightmare.

When it started pushing us along I thought it was going a bit wrong, so I was trying to get my window back. But I realised it was trying to arrange us all so I went along and tried to get my window back. I tried to get in front of people.

- It was a physical effort to get the tracking to recognise me. I had to walk in front of people to get my window back. There were other windows had appeared in between me and where my window was, so either people were moving or they were reading and I was getting in their way.
- Any windows in the space is assumed to be other people, so moving past windows is like being in the supermarket when people are looking at the shelves. You want to get through there quickly.

When I went in and everybody else moved I wondered why was it me again. I went to the right, down to the end. The person at the end stopped and there were other windows there that people hadn't moved to. I couldn't see or find my window, so I just took one that was there.

- Once I had a window I stood there so it wouldn't move again. I didn't want to interrupt everyone's experience. As I was reading the colour changed so I didn't know why, so I left.
- I would have preferred my own window, because it was someone else's experience. I didn't want to take it.
- I didn't want to move again in case it disturbed everyone else. I thought my window was on the left as this is where the space was, but it had already moved when I came in so I didn't want to do that again.

When I had a window on the left, everything started moving again and my got lost, then things moved again. It was too much to keep track and I could not read, so it was a bad experience.

When I came in a window popped up in a space on the left. When this happened the windows on the right seemed to move to allow a new window. But there were problems with tracking and windows going behind others.

- There were issues of windows being hidden and appearing and going. The shuffling was not good and it was hard to get a space and a window to read.

- There was a general movement of people when I came in and then a new window appeared in a gap. Windows either side moved to allow the window in and I was able to approach and use the window. It was not clear though because tracking and windows being covered.

Study 3 Trial 2 – Transcript 4 (Short)

There may be a problem with the speed windows move. Maybe non-linear movement, so small movements to begin with and larger movements later on. Indications about when the window is going to move.

There was only one slot left on the far left, there wasn't any movement in the windows, so it was clear that was where to go. It was clear because there were 6 stable windows and no movement in the windows. It was clear to see where to go. It was not linked with the other trials, it was just the place to be.

When somebody new came in it moved us to the right. Because I wasn't at the far left I didn't have to move so far. It was a surprise when it happened because you can't see people behind you so you don't know they are coming in, so it just happens all of a sudden. Once it had moved me though it seemed stable.

- There was something strange that there was a window to my left without someone looking at it. I'm not sure if there was a problem, or if there was someone I couldn't see, but it seemed strange.
- It seemed like there wasn't as much movement required in this trial. It may have been because there was so much space available in the third trial. I could clearly see the space and I would have been there anyway, so it was strange to be moved in to the space like that.

Once we had been moved it settled and was stable. I would have liked to have some degree of autonomy. I missed that. Once you are in there it feels like some of the people could have done with more space. Someone was on the join of the displays so I wanted to be able to move.

I came in and there was a gap and it found me and placed a window in front of me. I came in from behind the group so there was a marker moving across the top of the screen. So that movement had a domino effect on the other users. It was clear I was being tracked form a very early point.

Once I had caught up with the window I had after the adaptation I didn't notice anything else. Standing at the extreme right side there was very little to see.

I was standing in the middle when the adaptation happened. I concentrated on my window to try and catch up with it. It moved to the right and I followed it. The speed was not too bad this time, maybe because it didn't move very far.

The movement seemed fine in this test. It didn't go very far so it wasn't too bad.

I went in and found my place, but then someone was blocking my content. The window didn't move with me, I was expecting it to move with me, but it didn't so I couldn't get it to where I wanted it. Once people started leaving, all the windows started moving so I had to follow.

Twice my display was obscured for reasons that I couldn't tell. I didn't like that as I lost my window and didn't know how to fix it. Also there were issues of movement speed. There could be some lag between adaptation and movement.

It seemed crazy to be moved from the left to the right of the display when new people come in. It's strange that everyone would be moved to allow one person to come in to the space you were just in, when you would expect them to naturally want to go in to the space and use the open space that is already there. It seems unnecessary. And not allowing people to organise themselves in ways that they would naturally do anyway. It seems the most obvious in the thirst trial, where everyone starts on the left side and the new people could have gone to the right side.

Appendix F – Predicitive Study Results

N.B. The time coded video approach and analysis, and trascripts of user reporting have been omitted due to the volume of information captured. Instead the key word tables and simplifications are shown to highlight the similarities and clustering approach taken.

F1 Interview Questions

What do you think happened?

Where was everyone standing and how did you make your decision where to go?

Was there anything about where people were standing that maybe informed where you wanted to go?

When you walked in did you see anything moving or any changes to the display?

Was there anything about the display that may have been related to you?

Was there anything specific on the display that may have been related to your movement?

Do you feel you were forced or controlled to move anywhere?

Do you think you had any control over the system?

F2 Interaction Overview

Novice

User Study 4 – Interaction Overview

User Behaviours

Enters directly

Enters and slows approach

Pausing during approach

Stand back interaction

Correcting based on feedback

Following actors

Incorrect approach

Close to display

No correction

System Response

Large clear adaptation

Small clear adaptation

Incorrect adaptation

Final position with moving position marker

Final position with new content window

Secondary (incorrect) adaptation

Adaptation or position marker away from user position

Interaction

User responds to adaptation

User responds to actor movement

User is uncertain – slows or pause to assess adaptation

User responds to moving position marker

Final layout causes correcting behaviour

User makes their own decision – not following feedback

Vignette Overview

Novice User

Clustered first

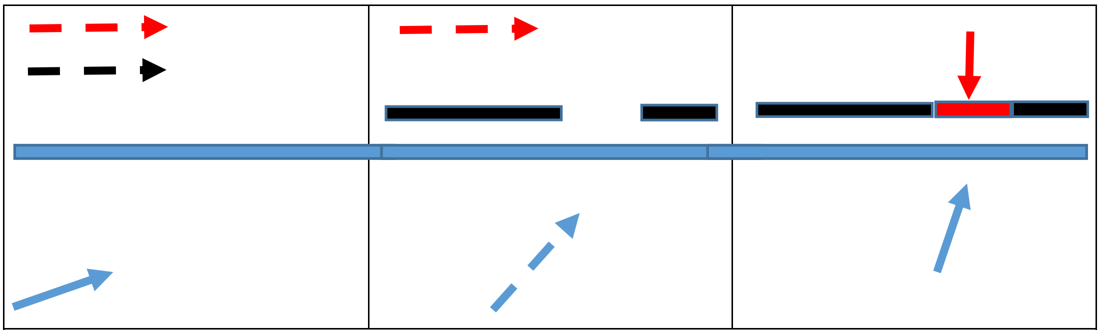


Fig. 1 – User initially responds to adaptation and slows upon entry – Position marker offers fine grained approach position.

N05 – 0135

Enters – Large early adaptation – Confused adaptation – User slows - Approaches gap

N08 – 0141

Enters – Large adaptation – Delay in response – User is following adaptation – User resolves based on position marker and final layout

N10 – 0145

Enters – Early adaptation – User slows – Approaches gap – User resolves based on position marker and final layout

N12 – 0149

Enters – Early adaptation – User responds to adaptation – Secondary adaptation – User resolves based on position marker

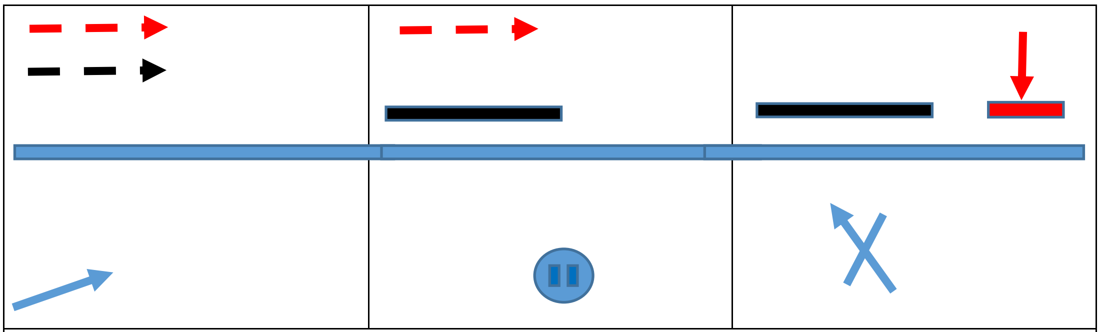


Fig. 2 – User observes the adaptation – Does not engage with the layout or position marker – Incorrect decision is made

N03 – 0131

Enters – Minimal early adaptation – User has limited engagement – On-going adaptation – User pauses to watch – Does not engage with the position marker – Incorrect approach

N15 – 0155

Enters – Not aware of adaptation – Large confused adaptation – User decision – Does not engage with position marker

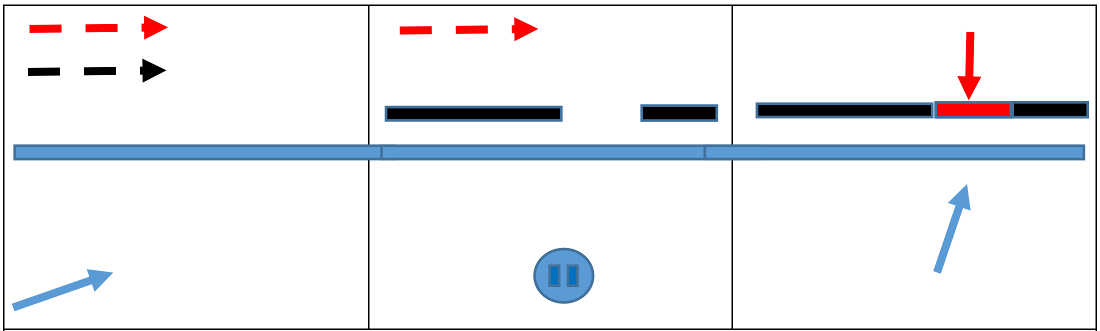


Fig. 3 – User Pauses for adaptation to finish before engaging

N01 – 0127

Enters – Adaptation – User Pauses to watch – Adaptation ends – User Approaches

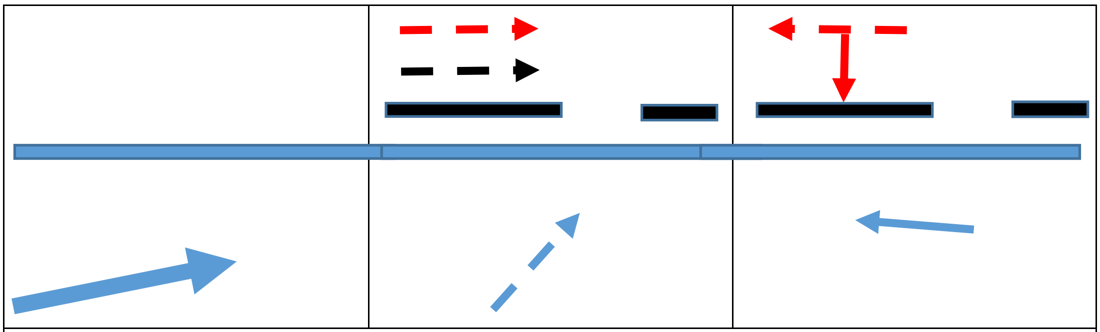


Fig. 4 – User initially approaches the right side of the display - Responds to adaptation – Secondary adaptation forces the user away - Position marker offers additional information.

N13 – 0151

Enters – Adaptation against decision – Forced to change decision – Following position marker

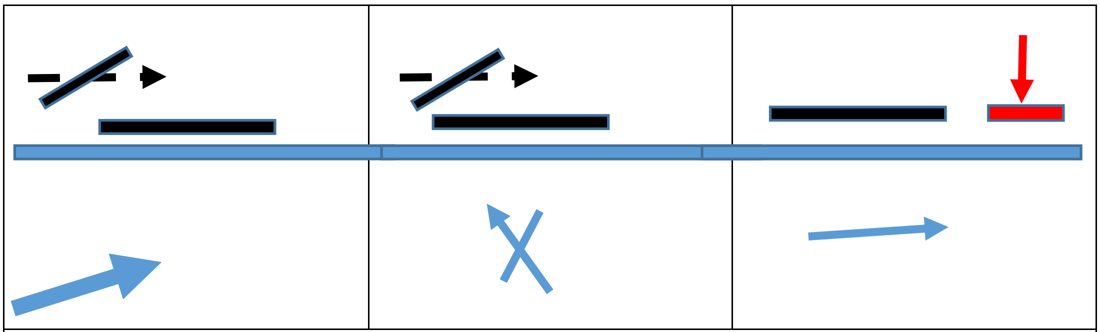


Fig. 5 – User makes a decision about where to interact – Incorrect adaptation in front of user decision – User changes decision – User corrects decision from final layout

N18 – 0162

Enters – User decision - Incorrect adaptation – User changes decision – User resolves based on position marker and final layout

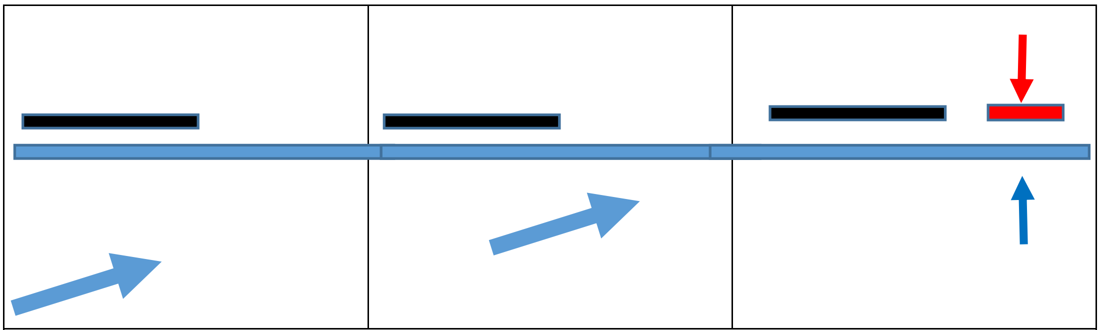


Fig. 6 – User makes a decision about where to interact – User does not respond to position marker moving past their location – Content window appears – User respond to final layout

N20 – 0166

Enters – No adaptation – User decision – User resolves based on final layout – No adaptation – Content is shown and user engages

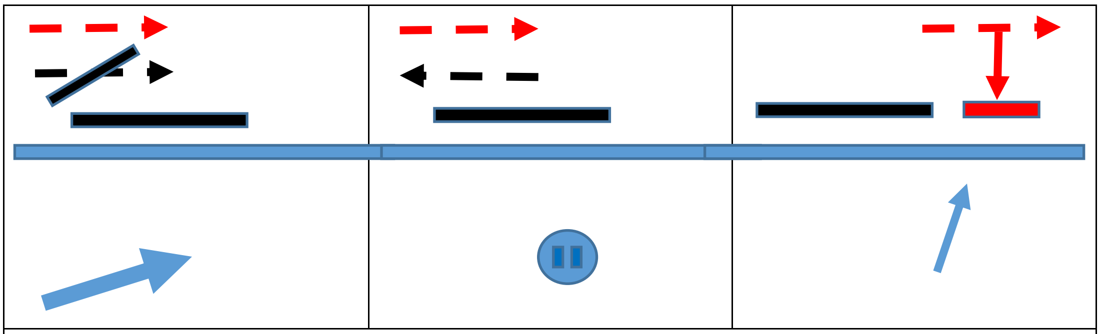


Fig. 7 – User makes decision about where to interact – Incorrect adaptation causes user to pause – User observes position marker – User responds to final layout.

N22 – 0170

Enters – User decision – Multiple incorrect adaptation – User pauses – Follows position marker

Distributed second

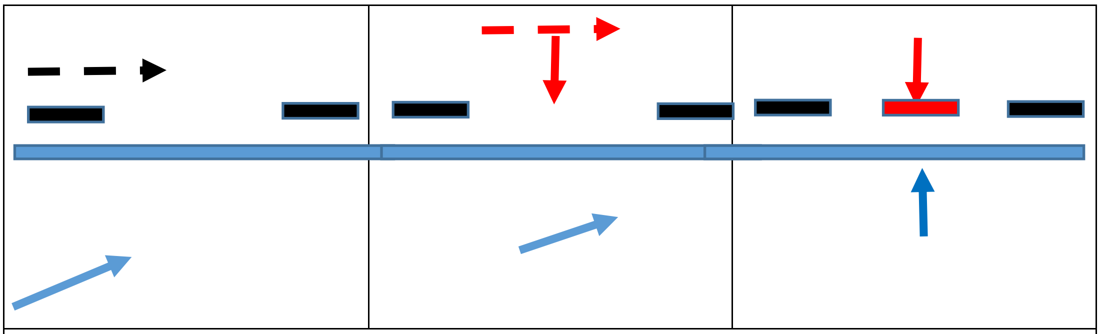


Fig. 1 – User enters space – Large clear adaptation – User responds to adaptation – Position marker moves in to the gap – New content window is shown – User responds to the new window

N08 – 2 0142

Enters – Large clear adaptation – User approaches adaptation – Position marker moves from the left – Content window appears

N10 – 2 0146

Enters – Early large adaptation – User approaches gap – Secondary adaptation – Does not impact upon user decision - User resolves based on position marker and final layout

N18 – 2 0163

Enters – Small adaptation – User resolves based on position marker

N20 – 2 0167

Enters – Large adaptation – User responds to adaptation – Secondary adaptation but no impact – User resolves based on adaptation

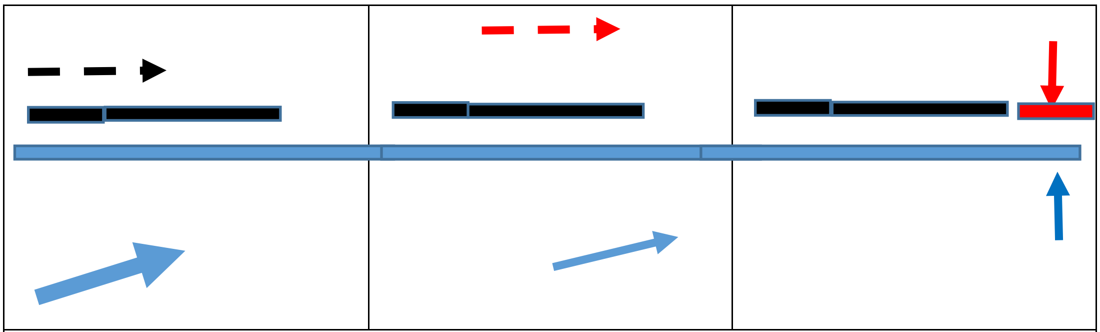


Fig. 2 – User moves confidently to the right hand side - Early large adaptation – User responds to adaptation – Position marker moves right and new content window is shown.

N12 – 2 0150

Enters confidently – Large adaptation in-keeping with decision – User responds to adaptation

N15 – 2 0156

Enters – Clear adaptation – User responds to adaptation – User resolves based on adaptation, position marker and final layout

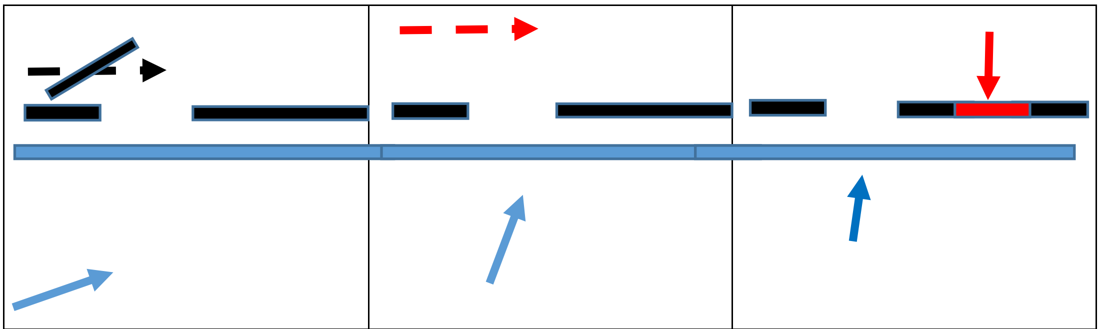


Fig. 3 – Initial incorrect adaptation – User responds to adaptation – Position marker moves past user – User notices marker but does not respond

N01 – 2 0128

Enters – Early adaptation – User makes a decision based on adaptation – Incorrect adaptation – User resolves based on final layout

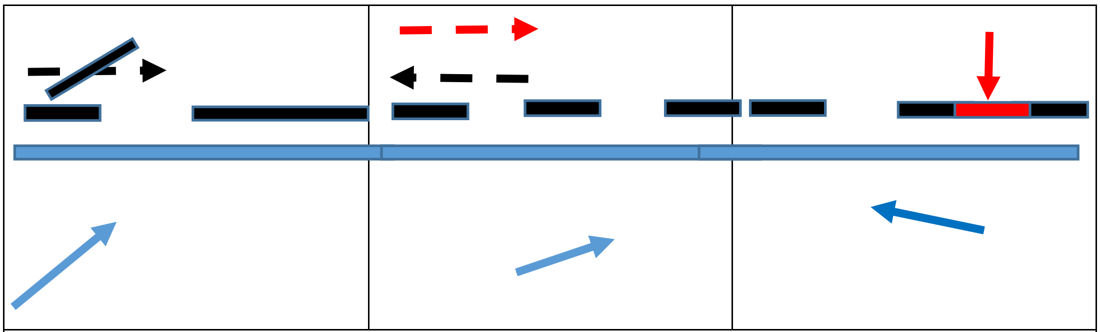


Fig. 4 – Initial incorrect adaptation – User responds to adaptation – Secondary adaptation – user responds - Position marker moves past user – User moves away from marker and moves left

N03 – 2 0132

Enters – Small adaptation – Leads users to location – Secondary adaptation and position marker – User follows secondary – New content window causes user to change their mind and return left

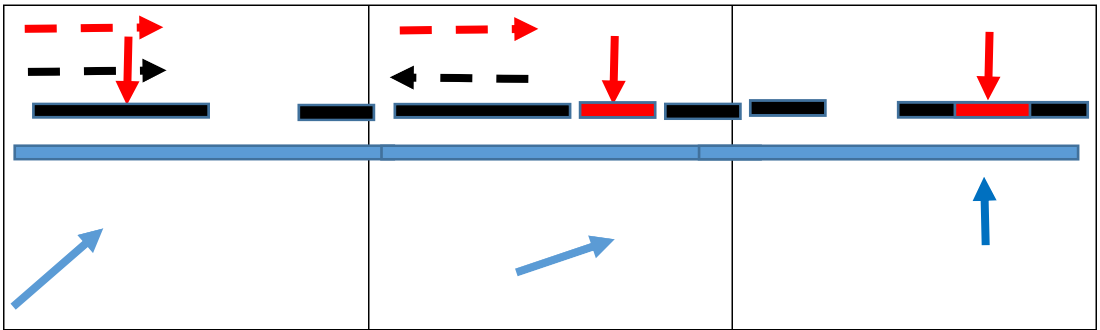


Fig. 5 – Initial adaptation moves all to the right and generates gap – User responds to movement on the left hand side – Interaction with position marker – Position marker moves to the right – User follow the position marker to the new content window.

N05 – 2 0136

Confident entry – Early adaptation – User follows adaptation – Incorrect adaptation – User resolves based on position marker and final layout

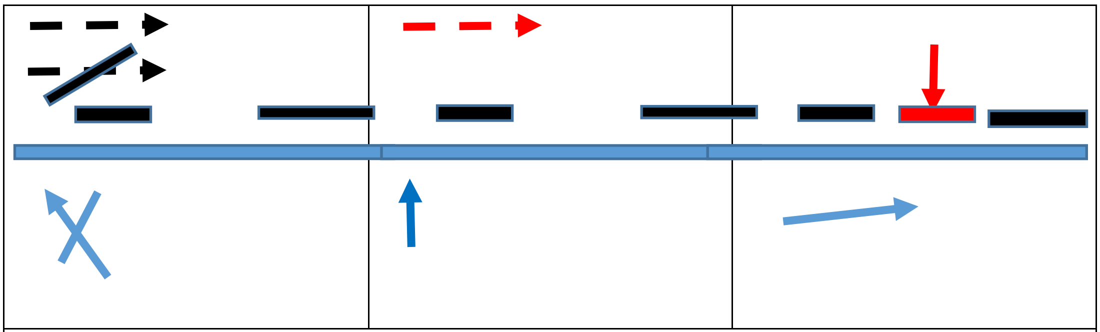


Fig. 6 – Large clear adaptation in centre – Secondary adaptation on left – Incorrect user response to secondary adaptation – Position marker moves past user – Content window is shown – User responds to final layout and position of new content window

N13 - 2 0152

Enters – Early adaptation – User incorrect decision – User resolves based on final layout

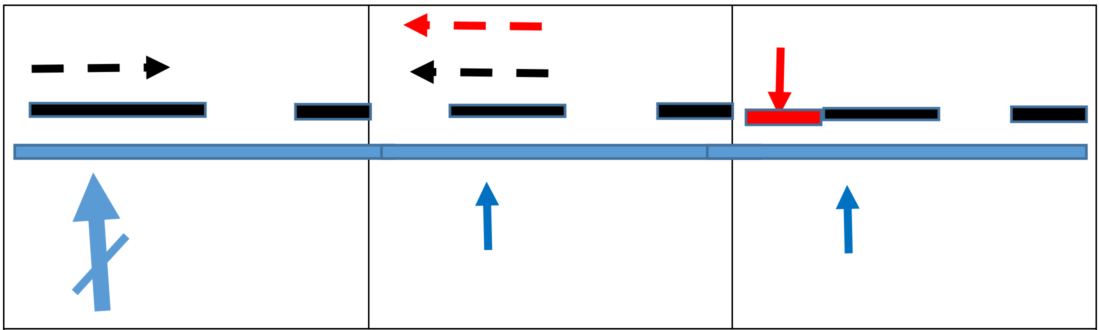


Fig. 7 – Early clear adaptation - User makes their own decision about approach – Secondary adaptation and position marker – User is close to display and does not respond to adaptation, position marker or final layout.

N22 – 2 0171

Enters – Small incorrect adaptation – User decision – User does not engage with adaptation – Some engagement with position marker

Distributed first

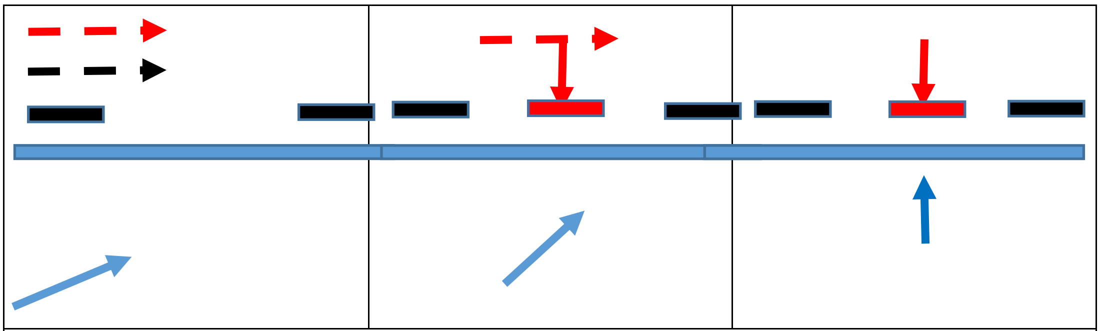


Fig. 1 – Large initial adaptation – User responds to adaptation – Position marker moves to the right – New content window is shown – User approaches content window

N09 – 0143

Enters – Large clear adaptation – User begins to approach the centre of the display – Position marker moves from the left in front of the user

N14 – 0153

Enters - Large clear adaptation – User slows and moves towards the adapted position – Position marker moves to the right of the user – User adjusts position to the new window

N17 – 0159

Enters – Large clear adaptation – User moves towards the adapted location – Position marker moves to the right – User approaches and engages with new content window

N19 – 0164

Enters – Large clear adaptation – User moves slowly and engages with position marker – User is moving towards the right end – Position marker moves to the right and user engages with window

N21 – 0168

Enters – Large clear adaptation – User slows – Position marker moves to the right – User moves to the right and engages with the correct position.

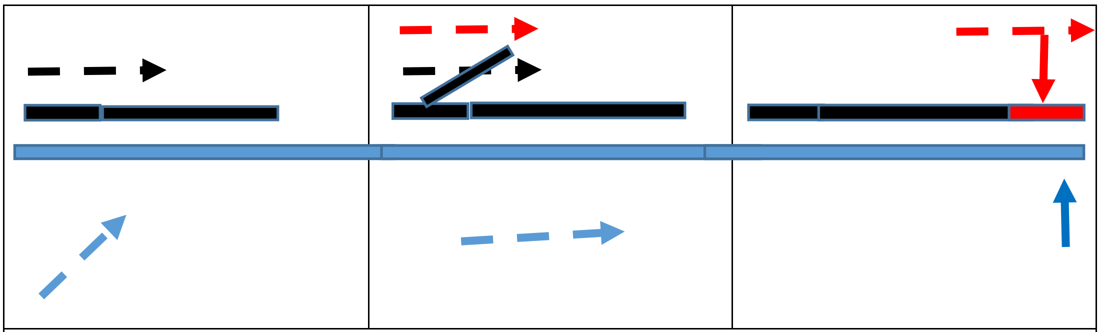


Fig. 2 – User enters slowly – Initial adaptation – User moves slowly – User responds to actor movement – Small incorrect adaptation at the predicted position – User approaches the location – Position marker moves to the location and new content window is shown – User engages

N11 – 0147

Enters – Clear adaptation on the right hand end – User begins to move to the right – Small secondary adaptation causes user to adjust away from the movement – Position marker moves in from the right – User arrives at the new content window

N16 – 0157

Enters – Large clear adaptation – Actors are slow to respond – User responds to display changes – Pauses and waits for clear space – Position marker moves to the right – User follows to get a window

Delay in actor response is similar to the incorrect secondary adaptation – There is uncertainty introduced in the users decision

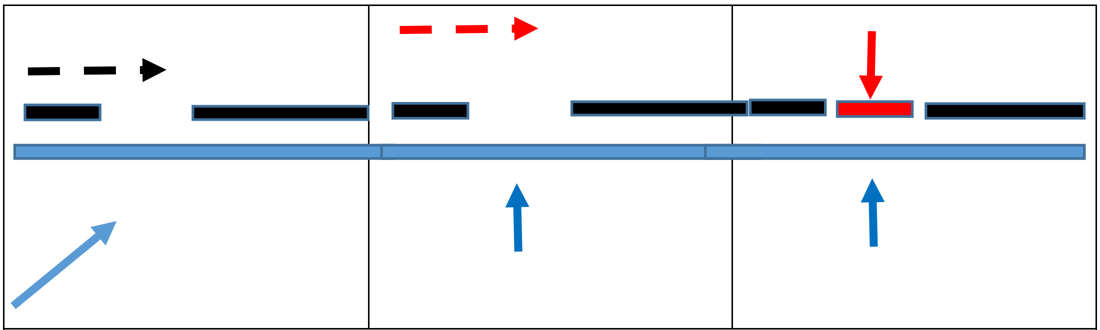


Fig. 3 – Initial adaptation – User responds to adaptation – Position marker moves in to space – New content window is shown

N02 – 0129

Enters – Small adaptation – User responds to adaptation and approaches directly

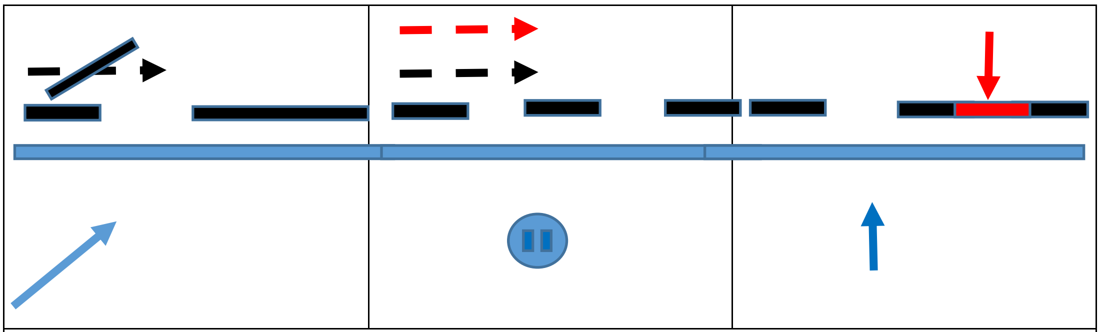


Fig. 4 – Initial incorrect adaptation – User responds to adaptation and pauses to observe – no clear interaction point - Secondary adaptation – User does not see or engage with the secondary adaptation – Position marker moves to the right – User does not respond to the marker

N4 – 0133

Enters – Small adaptation causing user to move towards display – No clear adaptation or new window – Cannot see or respond to position marker – User makes decision about where to stand

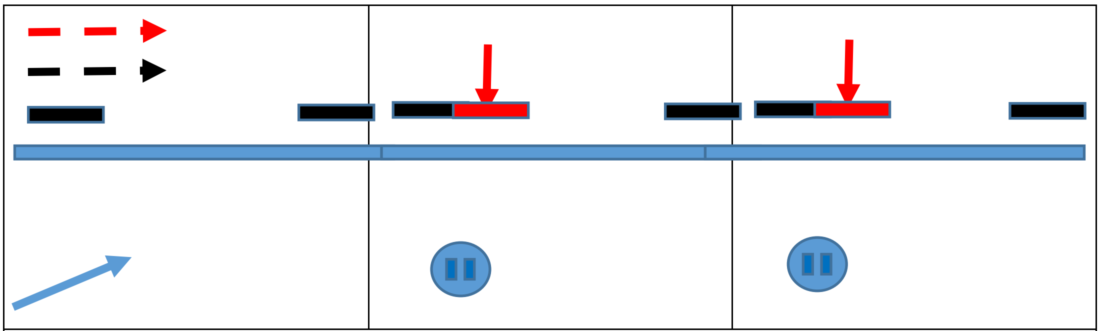


Fig. 5 – User enters space – Large clear adaptation – New window is hidden by actors – No clear point of interaction for the user – User does not engage any further

N06 – 0137

Enters – Large clear adaptation – No new content window or position marker – User pauses and waits for cue – User begins to approach the centre of the display

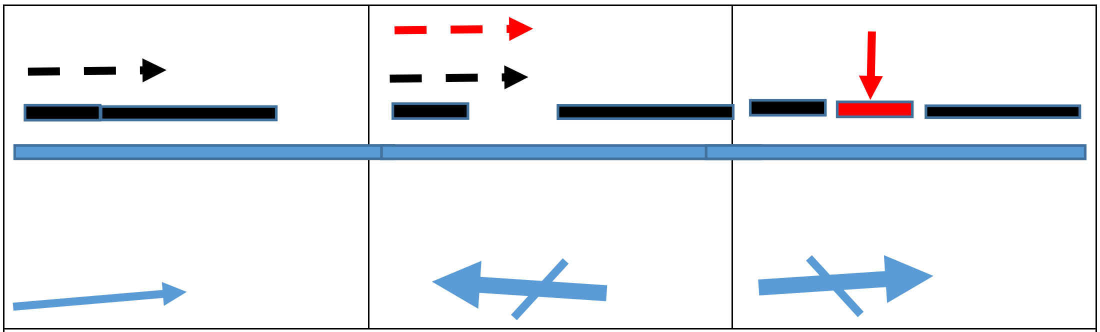


Fig. 6 – Initial adaptation – User does not engage with adaptation – User moves to the left of the display – Secondary adaptation and position marker – User does not engage – New content window is shown – User moves to the right of the space

N07 – 0139

Enters – Is not paying attention to the display – Does not see adaptation or position marker – Makes final decision about where to stand based on personal preference

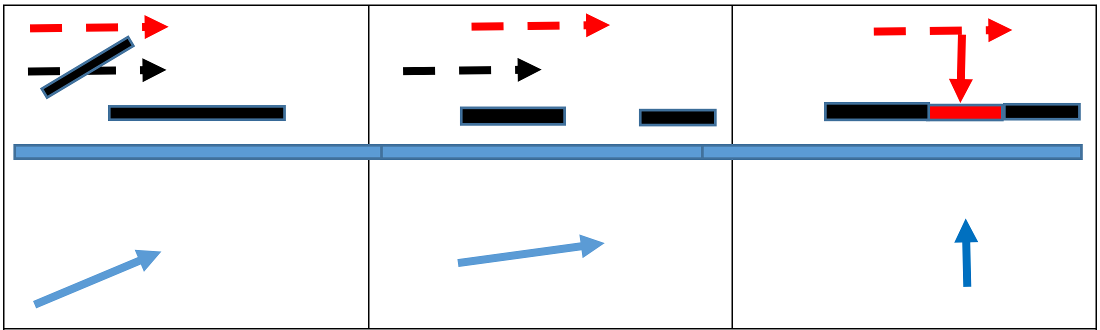


Fig. 7 – Incorrect initial adaptation – All actors are clustered – User moves to the rear of the cluster – Secondary adaptation creates gap in the cluster in-line with the user – Position marker moves in-line and new content window is shown – User engages with content window

N23 – 099

Enters – Incorrect adaptation – Actors are clustered together – User pauses – Position marker moves to the right - Final position is shown – User moves to the display.

Clustered second

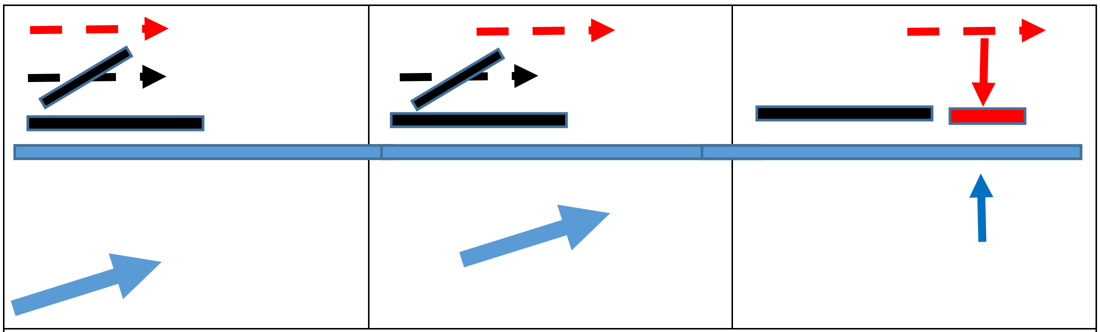


Fig. 5 – User makes a decision about where to interact – Incorrect adaptation in front of user decision – User changes decision – User corrects decision from final layout

N02 – 2 0130

Enters – Confused adaptation, jumble of movement – User decision to move to the right – Arrives at the right, position marker moves past – user resolves with the position marker and final layout

N09 – 2 0144

Enters – Small confused adaptations of actors – User moves tot eh right hand side – Position marker moves to the user position

N14 – 2 0154

Enters – Initial adaptation of one actor - User moves towards the right – Secondary adaptation of single actor – user moves away from actor position – Position marker and new content window shown – User approaches new content window.

N17 – 2 0160

Enters – User moves towards the right - Incorrect adaptation of actor four – User slows their approach – Secondary adaptation of actor four – Position marker moves to the right – User approaches and engages with new content window

N21 - 2 0169

Enters – Incorrect adaptation of actor four – User pauses – Secondary adaptation of actor four – Position marker moves to the right – User responds and moves to the right.

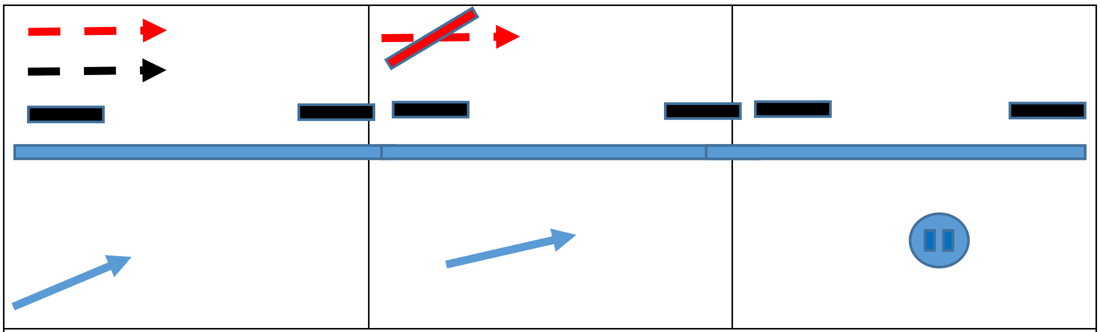


Fig. 5 – User enters space – Large clear adaptation – Position marker does not respond to user movement – No clear position or new content window – User pauses in front of adaptation

N06 – 2 0138

Enters – Large clear adaptation – Another user in the space – Adaptation was not related to the users behaviour – User follows the movement of the windows and arrives in a location – No position maker or new window to follow

N07 – 2 0140

Enters – Large adaptation – Slow response from actors – Unclear about position or relation of user behaviour – Position marker moves to the right – User does not respond – Stays in the centre

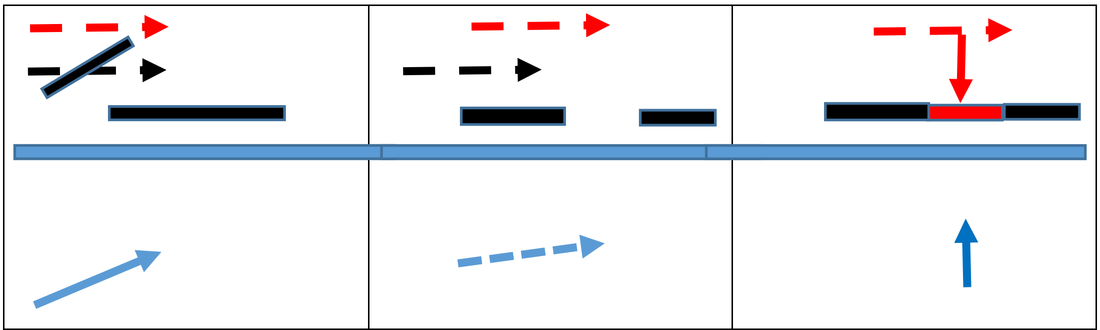


Fig. 7 – Incorrect initial adaptation – All actors move to the right – User is already moving to the right – User slows down as they move – Position marker moves to the right and new content window is shown – User responds to the position marker and new window

N19 -2 0165

Enters – Large adaptation – User approaches towards the adaptation – Secondary adaptation – User pauses – Position marker moves to the right and new content window appears – User approaches the display and engages with the new window.

N23 - 2 0100

Enters – Large adaptation to the right – User follows movement of actors – Position marker moves to the right behind the line – Secondary adaptation – User responds to adaptation and new window.

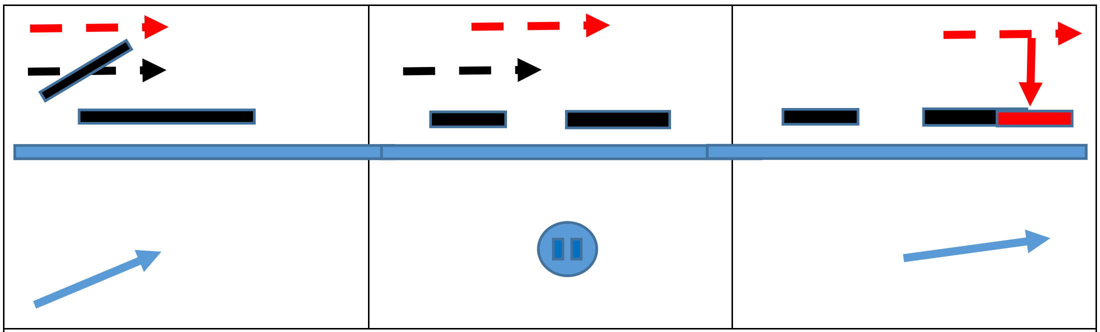


Fig. 7 – Incorrect initial adaptation – All actors are clustered – User moves to the rear of the cluster – Secondary adaptation creates gap in the cluster in-line with the user – User aligns to the gap - Position marker moves to the right and new content window is shown – User moves to the right and engages with content window

N4 – 2 0134

Enters – Small confusing adaptation – Delay in position marker – User resolves based on final layout and position marker

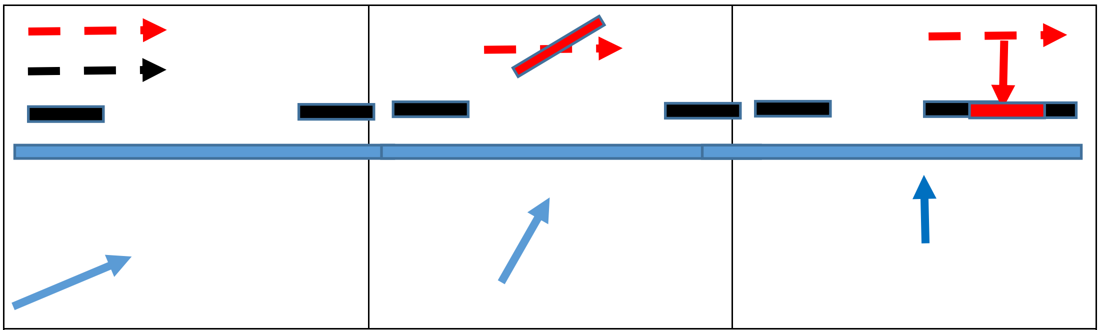


Fig. 1 – Large initial adaptation – User responds to adaptation – Tracking lost – New position marker moves to the right – New content window shown on right - User does not respond to position marker or new content window

N11 – 2 0148

Enters – Large clear adaptation – User responds to adaptation – Incorrect position marker moves to the right – User does not respond – No final content window – User is in correct position

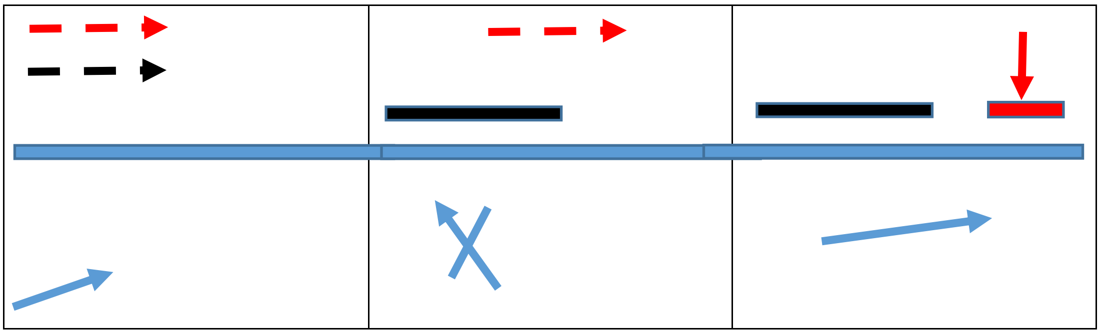


Fig. 2 – User observes the adaptation – Does not engage with the layout or position marker – Incorrect decision is made – Position marker moves to the right and new content window is shown – User notices the new window and moves to the right

N16 – 2 0158

Enters – Small adaptation of actor four – User makes incorrect decision about approach – Position marker moves to the right – User responds and follows

Repeat

User Study 4 – Repeat Interaction Overview

Vignette Overview

Repeat User

Clustered first

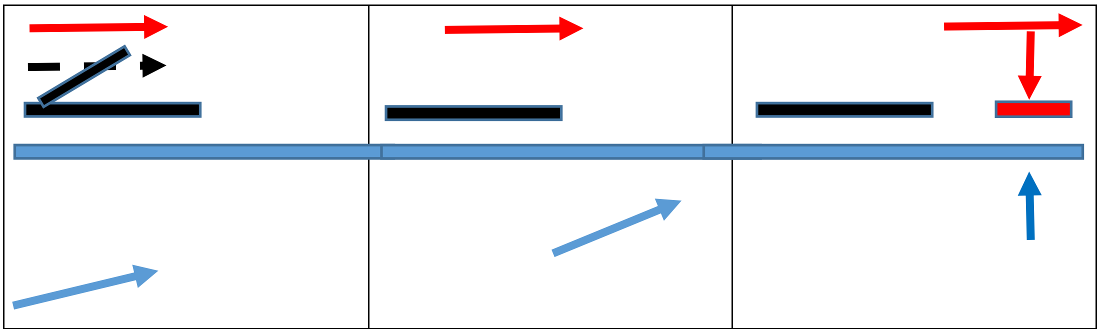


Fig. 1 – User enters and moves towards the right hand end of the display – User notices responsive position marker – User is moving to the right hand end watching the position marker – User arrives at the right end gap and new window is shown – Small correction in position.

R21 – 0120

User enters – Incorrect adaptation of actor windows – Windows jumble but no actor movement – User moves directly to the right hand side – Position marker moves to the right hand side – New content window is shown and user approaches

R23 – 0124

User enters – Small incorrect adaptation of actor windows – Jumbling of actor windows but no display movement of windows – user moves slowly across the space – New content window is shown on the right – user moves to the right hand end

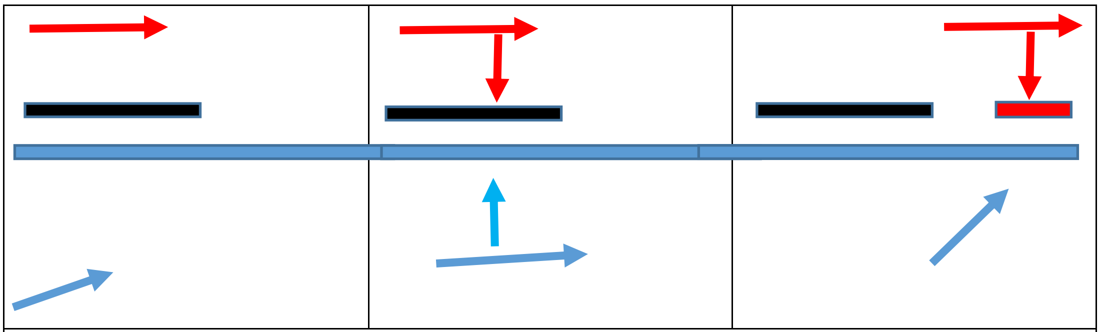


Fig. 2 – User moves behind actors and notices responsive position marker – User interacts with position marker and attempts to form a full window – No adaptation as system is in the responsive state - User moves to the gap on the right end and a new content window is shown.

R01 – 0075

User enters – Medium movement towards the centre of the space – No clear adaptation – Moves behind actors – Interacts with the position marker – Moves to the right until content window is shown – Approaches the display once the window is shown.

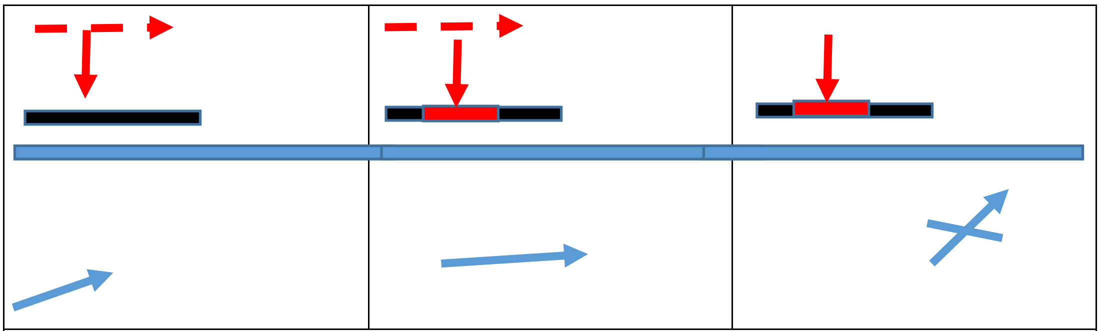


Fig. 3 – User moves behind actors but does not notice the position marker or new content window shown behind the actors windows – There is no clear adaptation as the new window is shown – user continues to move to the gap at the right hand end.

R03 – 0079

User enters – No clear adaptation – User appears to interact with position marker – New content window is shown behind the actors windows – No adaptation – user does not appear to notice the new window – User moves to the right hand end of the display – New position marker and content window are shown at the user position

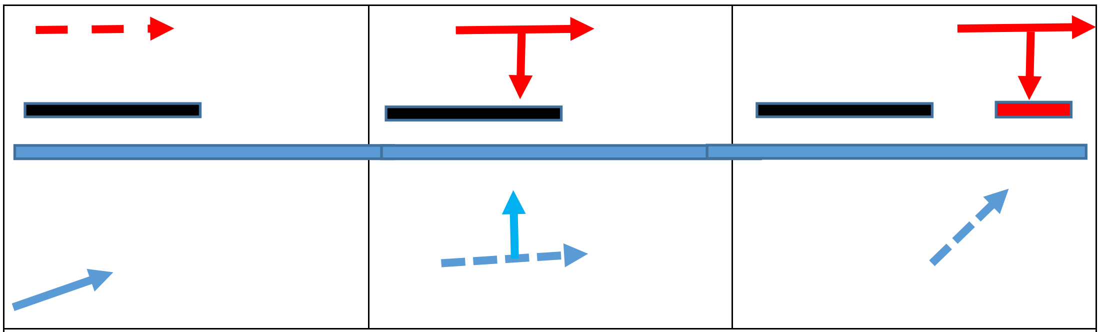


Fig. 4 – User moves behind actors and notices responsive position marker – User slows and watches the position marker leading to the right – Position marker arrives in right hand gap and new window is shown – User approaches new window.

R06 – 0085

User enters – Moves slowly across the space – Appears to notice and follow the position marker – Moves past the actors and the new content window is shown – User approaches the new window

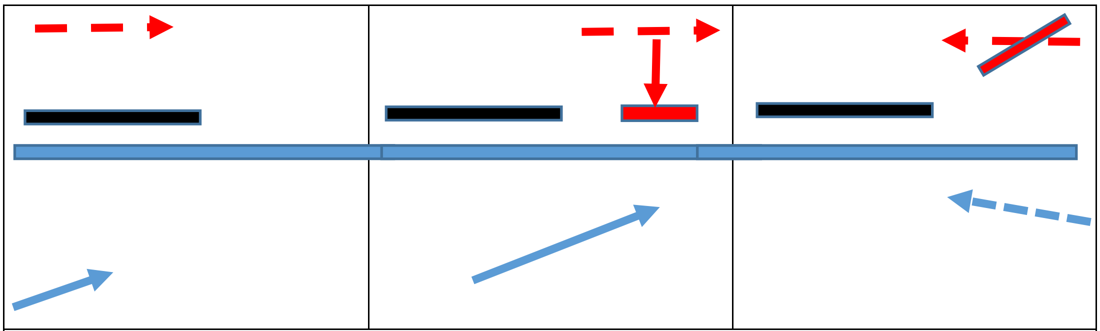


Fig. 5 – User directly to the right hand gap – Position maker follows user and new window is shown – Secondary incorrect position marker moves to the left – User begins to follow but looks towards the gap – User is not able to understand the relationship or interaction

R11 – 0095

User enters – Moves past the cluster to the right hand side – Position marker follows user – User arrives at the display – New adaptation and position marker moves to the left – User begins to follow marker – Looks back to the right

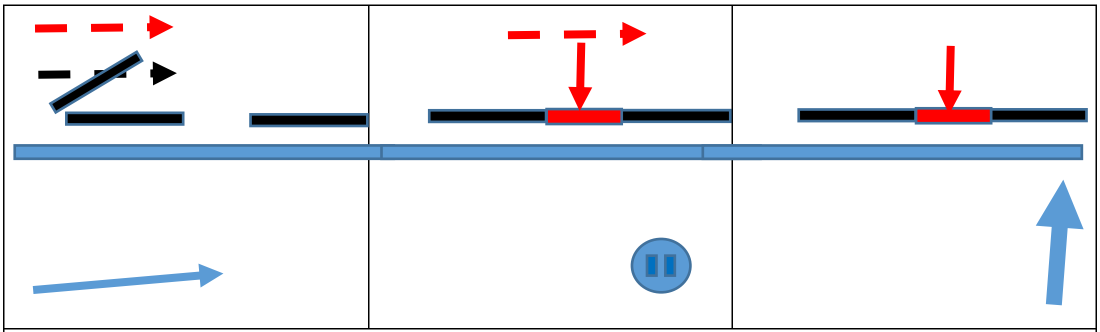


Fig. 6 – User begins to move to the right hand end of the display – Incorrect adaptation moves actors to the right – Position marker moves to the right and new window shown between actors windows – user cannot clearly see the new window – User approaches the display directly at the right hand end

R12 – 0097

User enters – Moves to the right hand side – Incorrect adaptation – Windows move in front of user – New content window is shown in between actor windows – User does not appear to notice new window – User continues to the far end of the display – New position marker – User attempts to interact with the new marker

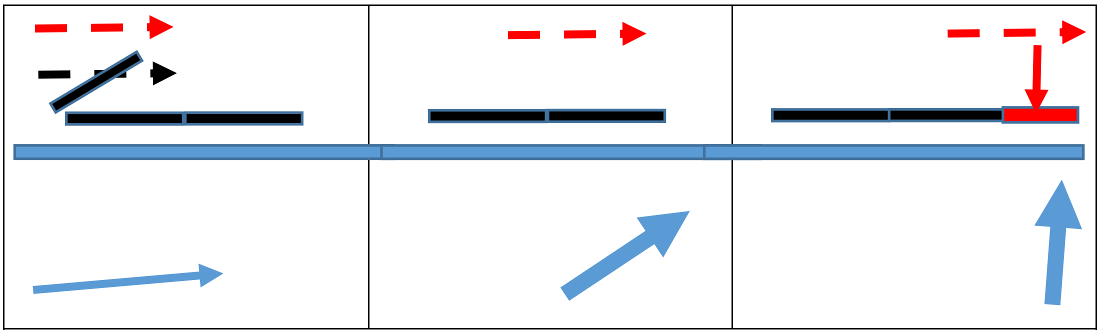


Fig. 7 – User begins to move to the right hand end of the display – Incorrect adaptation moves actors to the right – User continues to approach the right hand end of the display ignoring the adaptation and position marker - Position marker moves to the right and new window shown

R13 – 0103

User enters – Moves directly to the right hand side – Incorrect adaptation moves windows in front of user position – User watches the position maker move from the left – Does not respond to the incorrect adaptation – Waits for the position marker and new content window

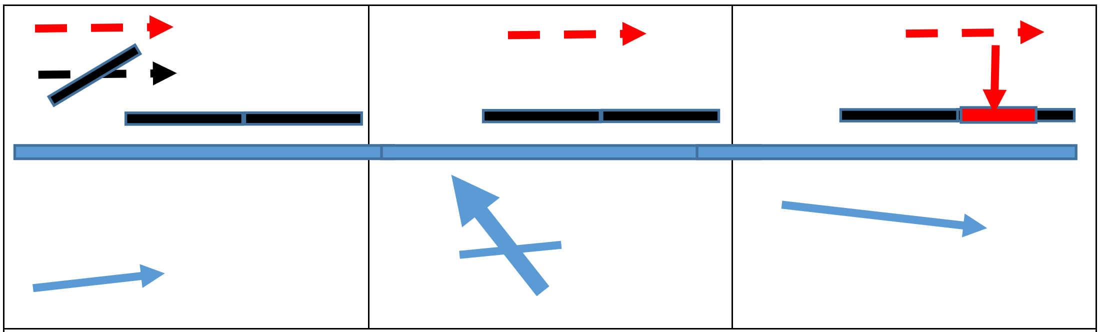


Fig. 8 – User begins to move to the right hand end of the display – Incorrect adaptation moves actors to the right – User responds to adaptation and moves to the adapted left hand gap – Position marker moves to the right and a new window is shown – User notices new window and position marker and moves to the right

R16 – 0108

User enters – Early incorrect adaptation – All actors move to the right in front of the user – User begins to follow actors – Changes direction and moves to the new gap on the left – Position marker moves to the right behind the actors – User looks to the right toward the position marker – Begins to move towards the position marker and new content window

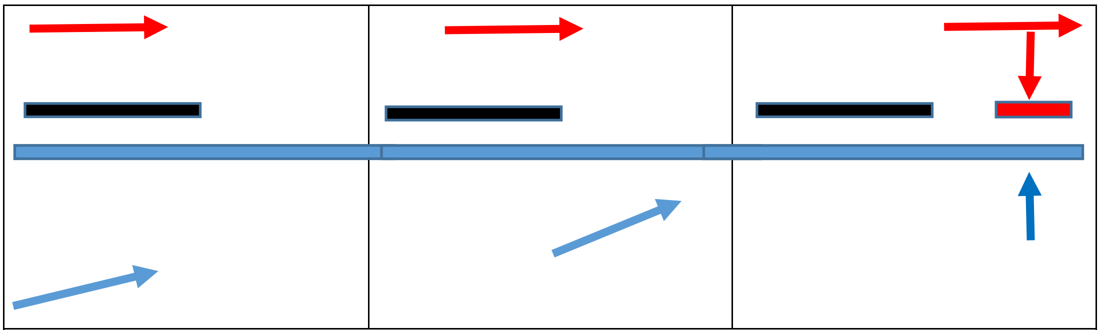


Fig. 9 – User enters and moves towards the right hand end of the display – User notices responsive position marker – User is moving to the right hand end watching the position marker – User arrives at the right end gap and new window is shown – Small correction in position.

R0117 – 0110

User enters – Jitter in actor windows but no adaptation – User moves to the right hand end of the display – User waits for the position marker before approaching the display

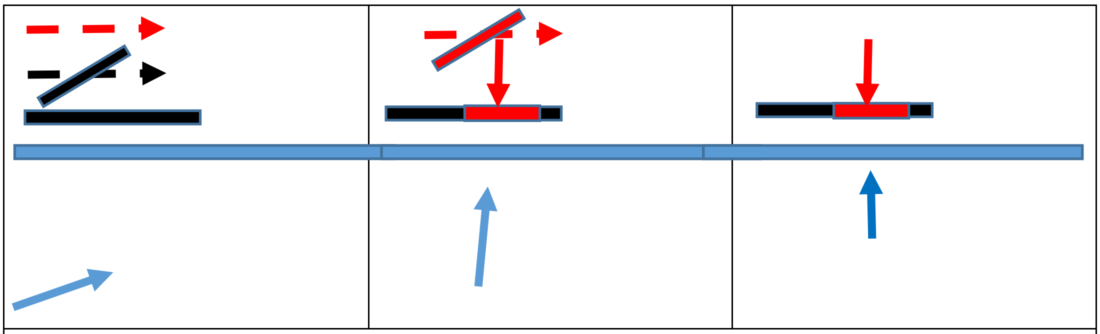


Fig. 10 – User enters – Initial incorrect adaptation causes jumbling of actor windows – User responds to position maker – No leading movement of position marker – User attempts to interact with position marker and form full window

R19 – 0114

User enters – Incorrect adaptation – Actors changes places but do not move across the display – Position marker is behind the actors positions – User approaches the back of the group – New content window is shown behind the group – User interacts with the window and joins the line

Distributed second

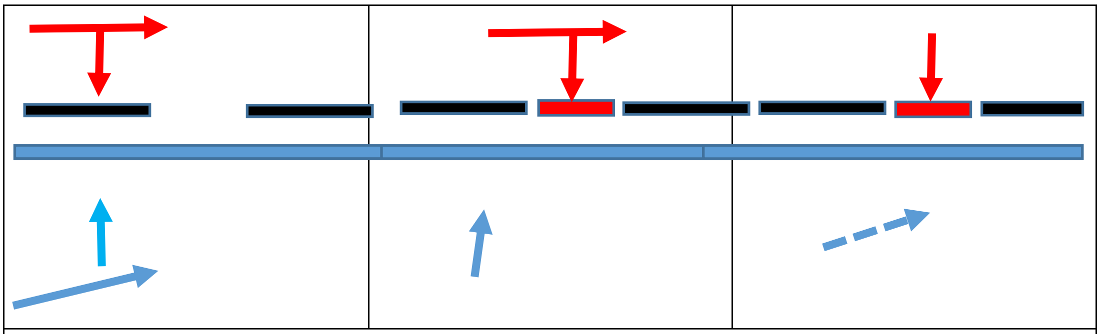


Fig. 1 – User enters and engages with the position marker – Position marker moves to the right and a new window is formed in the centre gap – User notice new window and approaches

R01 – 2 0076

User enters – Interacts with position marker – No clear adaptation – User pauses in first gap – Position marker moves right past the user – User follow the marker – New content window is shown – User stops in front of new window and approaches display.

R06 – 2 0086

User enters – Moves quickly in to space – Pauses and notices position marker – Watches position marker move past their position – User moves to the left to test position maker interaction – Position marker moves to the right – User watches marker and moves to the right – New content window is shown in the third gap – user moves towards the new window.

R21 – 2 0121

User enters – Early clear adaptation of right hand end – Position marker is in line with left hand gap - User approaches the first gap on the left – Position marker moves to the right hand end of display at adapted gap – New content window is shown on right hand end – User notices new window and moves to the right hand end.

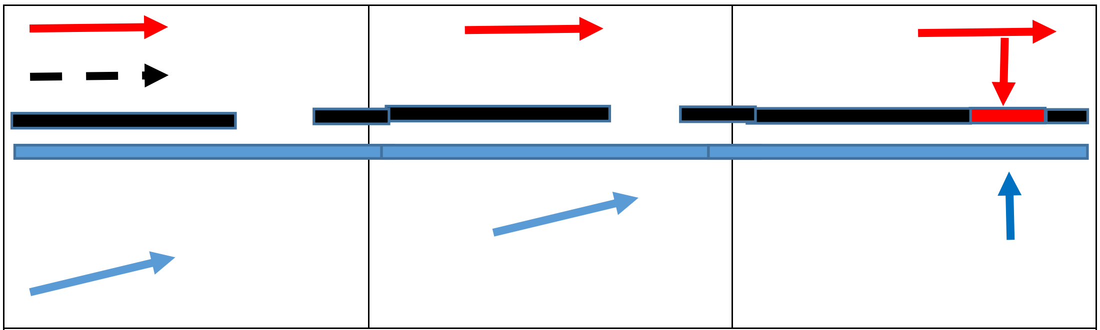


Fig. 2 – User enters and initial early adaptation on the right hand end – User engages with the adaptation and moves towards the gap – Position marker moves to the adapted gap and a new window is shown – New window is formed after the user arrives – User responds to the new window and adjust position to interact

R12 – 2 0098

User enters – Early large adaptation – User moves towards adaptation – User notices position marker but continues towards adaptation – User arrives in gap and new content window is shown.

R17 – 2 0111

User enters – Small adaptation of the right hand end – User pauses in the middle of the space and watches the position marker – Position marker moves to the right of the user and a new content window appears in the last gap – User moves to the right in line with the content window

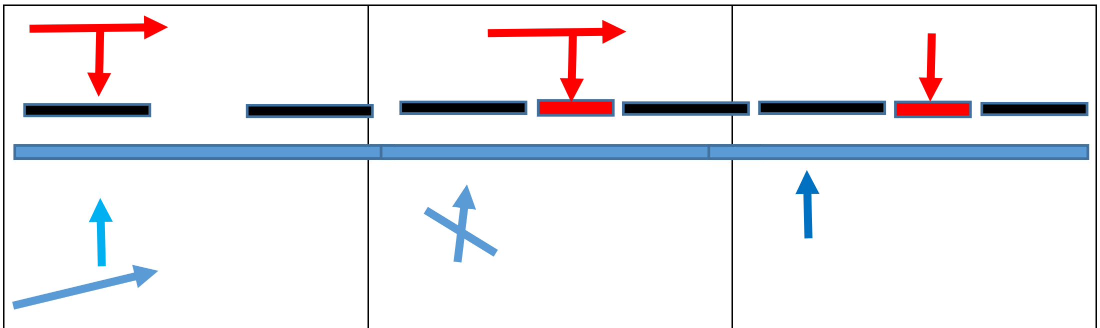


Fig. 3 – User enters and engages with the position marker – Position marker moves to the right and a new window is formed in the centre gap – User does not notice the new window formed and engages with actor windows in the initial position

R03 – 2 – 0080

User enters – No adaptation – Moves slowly to the centre of the space – Notices position maker – Aligns to the first gap – Position marker moves to the right – User approaches the first gap – Position maker moves to the second gap and a new window is shown – User does not notice the new window and engages with an existing window.

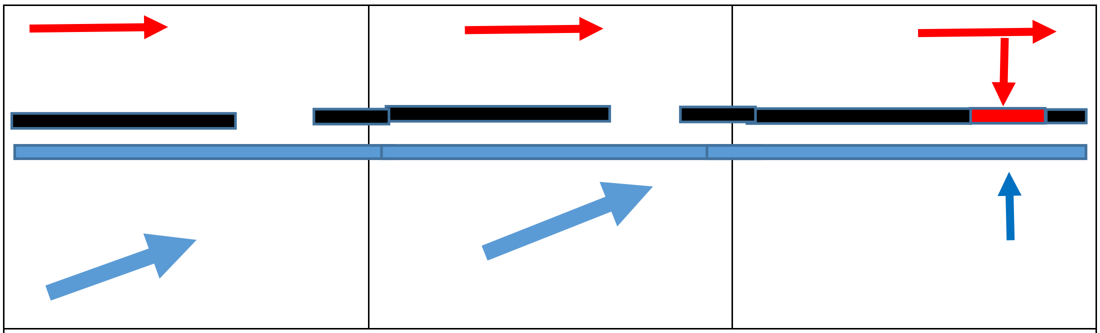


Fig. 4 – User enters and moves towards the right hand end of the display – User approaches the right hand gap directly – Position marker follows user – new content window is shown and user engages with the new window directly

R11 – 2 0096

User enters – Moves directly to the end of the display and last gap – Position marker follows user – Arrives at the final gap and new window is shown – User changes angle to align with the window.

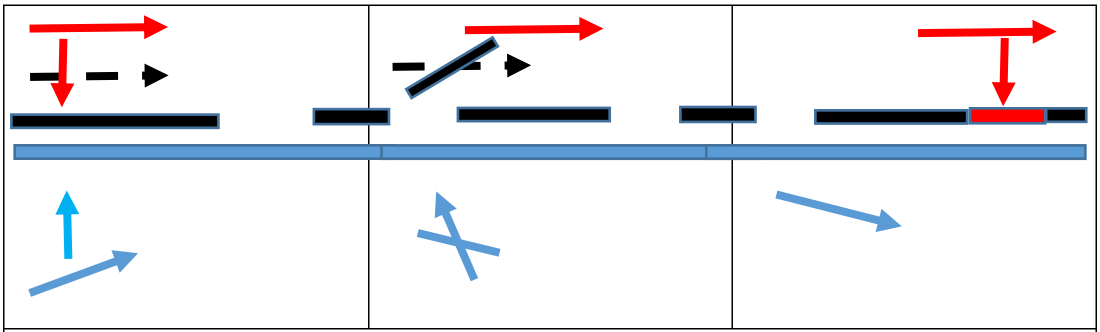


Fig. 5 – User enters and initial early adaptation on the right hand end – User engages with the position marker on the left hand end – Secondary incorrect adaptation of the left hand end – User approaches secondary adaptation location – Position marker moves to the right – New window is shown in the first adaptation – User responds and approaches the new window.

R13 – 2 0104

User enters – Early adaptation – Clear gap created with incorrect adaptation of multiple windows moving to the right – User makes a decision to move to the left of the display toward the current position marker – Position marker moves to the right – No content window shown at the user position – Position maker moves to the left hand side – New content window is shown – User moves towards the new content window

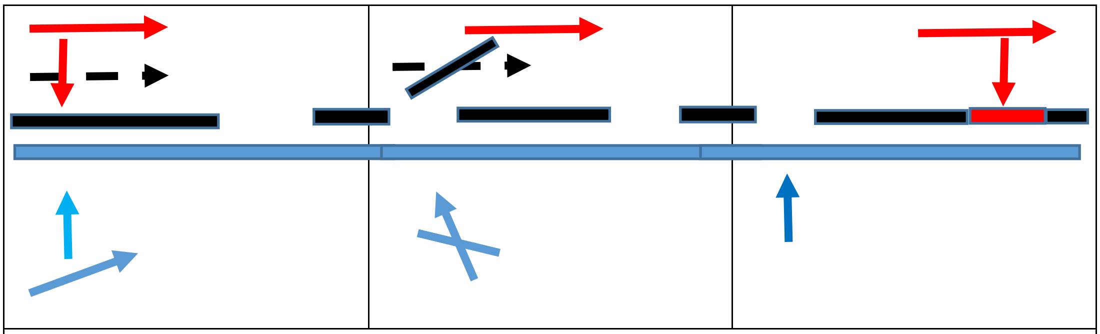


Fig. 6 – User enters and initial early adaptation on the right hand end – User engages with the position marker on the left hand end – Secondary incorrect adaptation of the left hand end – User approaches secondary adaptation location – Position marker moves to the right – New window is shown in the first adaptation – User does not respond to the adaptation or position marker.

R16 – 2 0109

User enters – Early initial adaptation on the right hand end – User begins to approach the adaptation – Secondary incorrect adaptation on the left hand end - User changes direction and approaches the left hand gap – Position maker moves to the right hand end – User does not respond to the position marker – Engages with an actors window on the left.

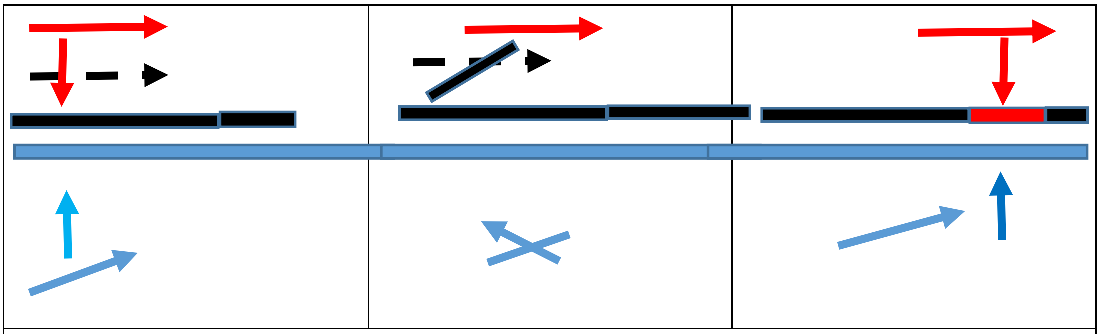


Fig. 7 – User enters and initial early adaptation on the right hand end – User engages with the position marker on the left hand end – Secondary incorrect adaptation removes the gap – User makes incorrect decision and moves to the left – Position marker moves to the right and a new window is formed – User responds to the new window and moves to engage

R19 – 2 – 0115

User enters – Small early adaptation on the right end of the display – User approaches the adaptation – Adapted window moves back to starting position – User pauses and changes direction towards the position marker – Marker moves past the user position – New content window is shown on the right – User moves towards the new window

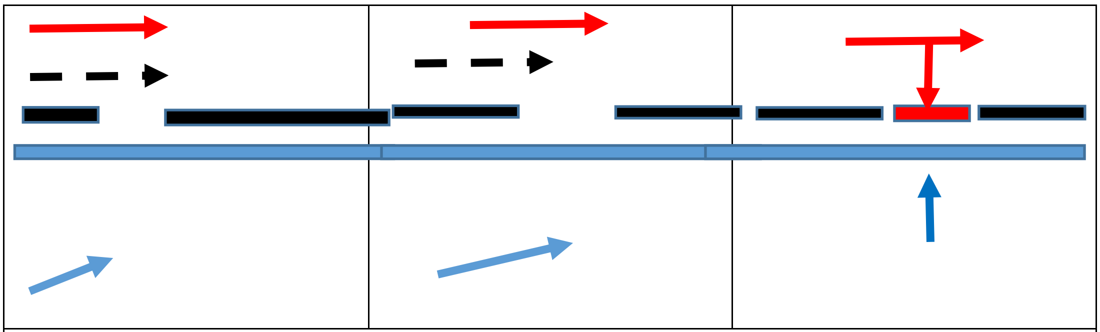


Fig. 8 – User enters and initial early adaptation on the left hand end – User begins to engage with the adaptation – Secondary adaptation to the right – Position marker moves to the right – user engages with the position marker and adapted gap – user engages with new window

R23 – 2 0125

User enters – Early clear adaptation of left hand windows – User slows and stand in line with the adaptation – User begins to approach adapted gap - Position marker moves to the right of the adapted gap – Secondary clear adaptation on the right of the display – Position marker moves to the right – User approaches the new content window

Distributed first

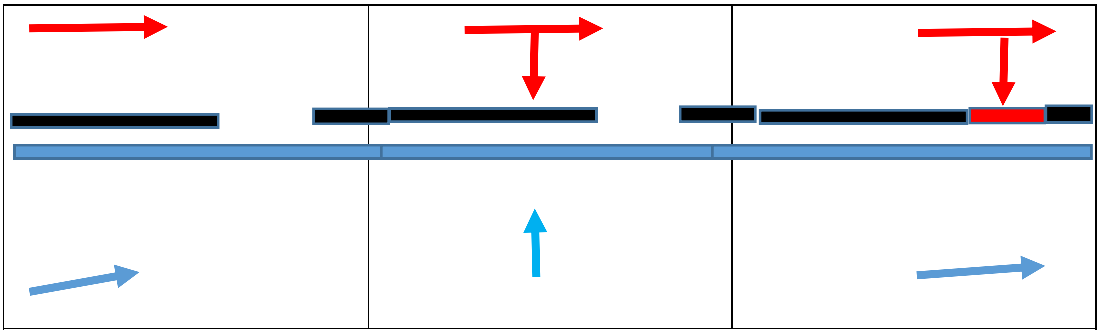


Fig. 1 – User enters and initial moves to the centre of the space – No initial adaptation – User notices position marker and pauses – Position marker moves past user position – User moves to the right and stands in front of gap – Position marker moves to gap and new window is shown

R02 – 0077

User enters – Moves to the centre of the space – Position maker moves to the right past the user position – User begins to move to the right – Position marker moves to the right hand gap and new content window is shown – user stands in line with the new window but does not approach

R05 – 0083

User enters – User slows In line with the left gap – Position marker is in line with the user and left gap – User begins to approach the left hand gap – Position marker moves right past the user position – Position marker moves to the right and a new window is shown in the next gap – User moves in line with the new content window

R09 – 0091

User enters – Moves in line with the left hand gap – Position marker is in line with the user – User slows movement and watches position marker – Position marker moves to the right of the user – User begins to move to the right – New content window is shown in the middle gap – User moves in line with the new window but does not move forwards

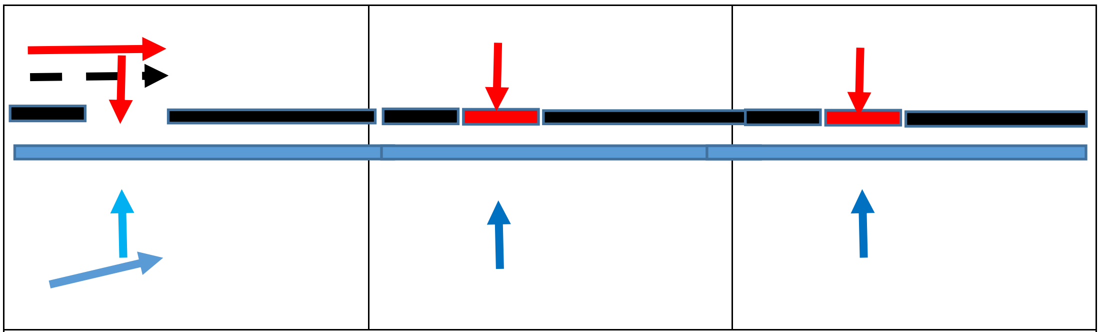


Fig. 2 – User enters and initial interaction with window in responsive state – Window shown in first gap – User interacts and approaches display – No further adaptation of the display – User does not join the line of actors – No actor movement

R04 – 0081

User enters and pauses in line with the left hand end of the display – Content window is shown in the left hand gap in line with the user in the responsive state – User interacts with the window – user approaches the left hand gap to interact with the window

R07 – 0087

User enters – Moves towards the centre of the space and slows – Position marker moves in to the left hand gap in line with the user – User begins to approach the position marker and gap – New content window is shown in the second gap – User approaches the new content window

R10 – 0093

User enters and approaches the left hand gap directly – Position marker moves in line with the user and a new content window is shown – User interacts with the new window

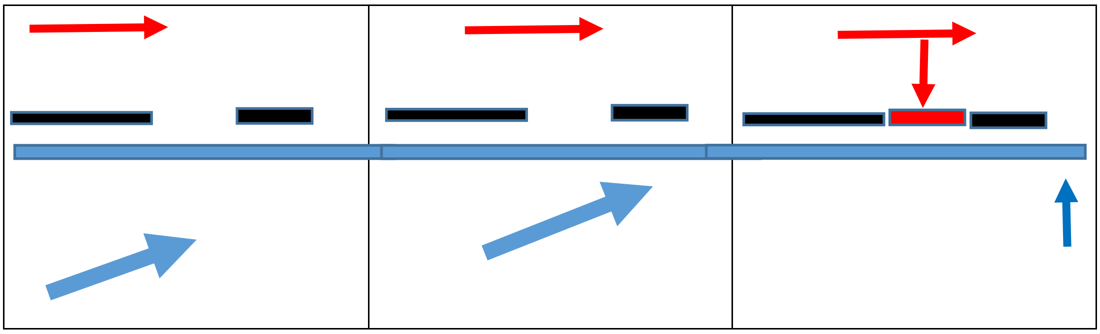


Fig. 3 – User enters and moves directly to the centre of the space – Position marker is following the user – User does not engage with the position marker - User pauses in the centre and moves directly to the right end gap – New window is shown in the centre gap – User does not engage with the new window – No clear adaptation of the display

R08 – 0089

User enters and moves directly to the centre of the space – Position marker moves in line with the user in the middle gap – User moves to the right ahead of the position marker movement – Position marker stops in the centre gap and new content window is shown – User is in line with the actors and does not respond to the new content window

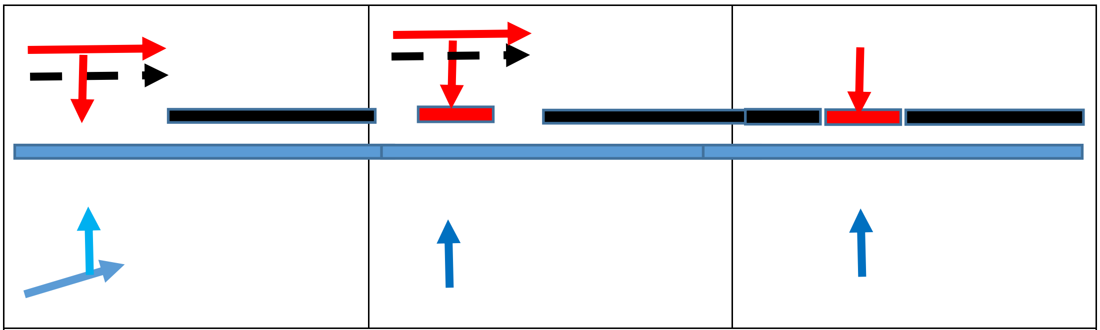


Fig. 4 – User enters and initial adaptation of windows to the right – User engages with the position marker – Responsive window and position marker – Actors move to the right and user interacts with new window.

R13 – 0101

User enters – Early clear adaptation of actors moving to the right – User approaches the left hand adapted gap directly – New content window is shown

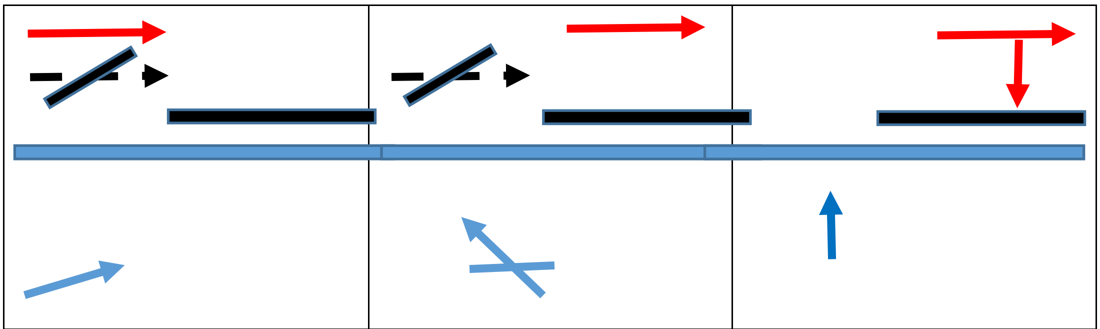


Fig. 5 – User enters and initial incorrect adaptation of right side of display – Position marker moves to the right – Extremely confused adaptation – User does not notice position marker – User responds to adaptation and moves to the left – User is not able to see the position marker

R15 – 0105

User enters – Confused jumble of actor windows – User pauses – Position marker moves right past the user position – User moves to the adapted gap on the left of the display – New content window is shown on the right of the display – User does not see the position marker or new window.

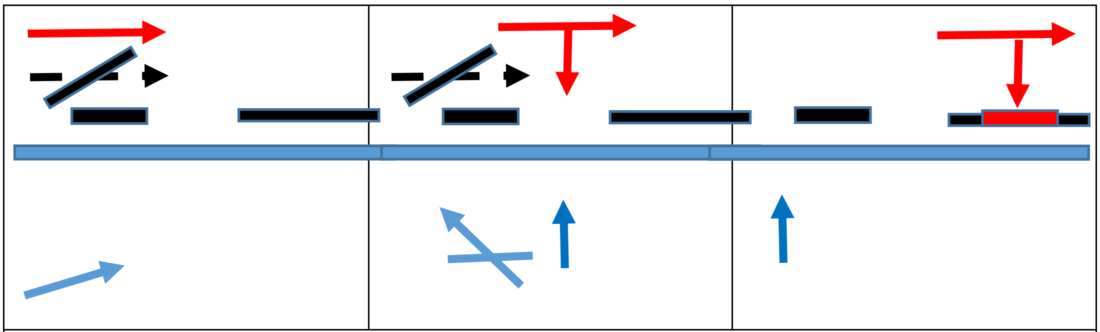


Fig. 6 – User enters and initial incorrect adaptation – Actors move to the right – Slight movement of left, strong movement of the right – User briefly engages with the position marker – User decides to move to the left end – New window is shown but user does not notice

R18 – 0112

User enters – Early clear adaptation of windows to the right – Several gaps created on left and in centre – User slows and begins to approach left hand side of display – Position marker moves past the user to the right – User moves to the left hand end adapted gap – New window is shown in the right hand gap – User looks across display but does not move – user interacts with actors window on the left hand end of the display

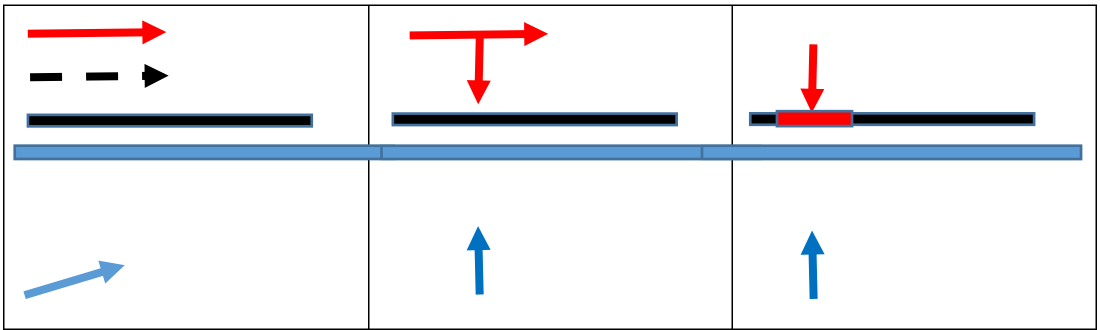


Fig. 7 – User enters and initial small adaptation of right hand end – User is moving towards the right end but notices position marker – User engages with position marker – New window is shown behind actors window – User attempts to interact but does not approach any closer

R20 – 0118

User enters – Early small adaptation on the right hand end – User enters and pauses in line with the position marker – New window is shown in line with the user behind an actors window – user attempts to interact with the window but there is no movement – User does not approach closer

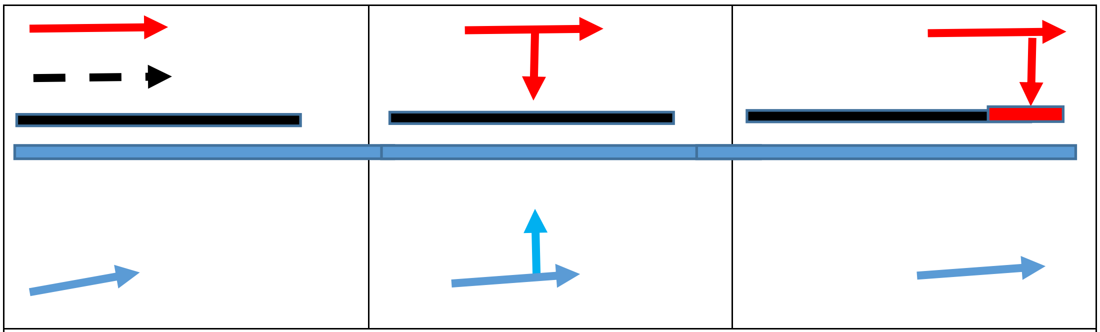


Fig. 8 – User enters and small initial adaptation of right hand end – User moves in to the space and notices the position marker – User engages with position marker and waits for it to moves past their location – User approaches the right hand gap and new window is shown – user engages with the new window but does not approach.

R22 – 0122

User enters – Small early adaptation of the right hand actor – User moves in to the space and pauses in line with the left hand gap – Position marker moves past the user position to the right hand end gap – User watches the position marker and begins to move to the right – user is in line with the new content window but does not approach closer to the display

Clustered second

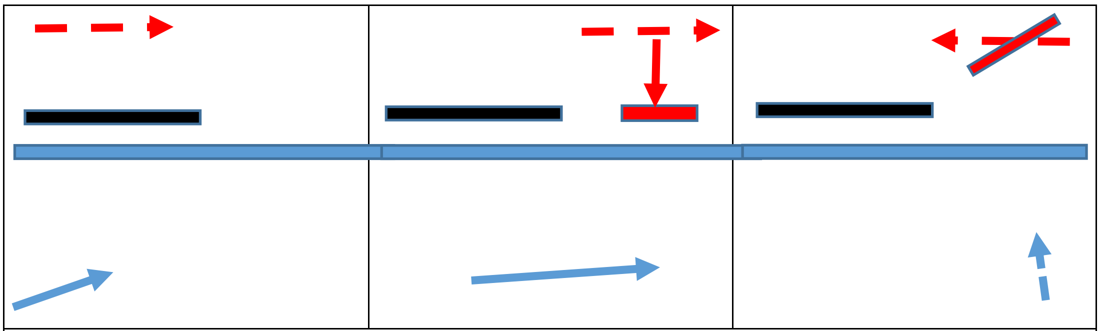


Fig. 1 – User directly to the right hand gap – Position maker follows user and new window is shown – Secondary incorrect position marker moves to the left – User begins to follow but looks towards the gap – User is not able to understand the relationship or interaction

R02 – 2 0078

User enters – Moves directly to the right hand side – Position marker moves to the right in line with the user position – No new window is shown – Position marker begins to move to the left – User attempts to interact with the right hand gap but no window is shown

R05 – 2 0084

User enters – User moves directly to the right hand end gap – Position marker follows user to the right hand end – Incorrect secondary movement of the position marker to the left hand end – User watches the position marker move away – User attempts to interact with the right hand gap

R04 – 2 0082

User enters and moves directly to the right hand end of the display along the back line – Position marker disappears and appear in line with the user – User interacts with the position marker – Incorrect movement of the position marker to the left – New content window is shown on the left of the display behind the actor windows – User moves to the left in line with the position marker – User does not approach the display but stays in the back line.

R08 – 2 0090

User enters and moves directly to the right hand end gap – Position marker follows the user – User arrives at the right hand end of the display – Secondary incorrect adaptation of the position marker to the left – User watches the position marker move to the left and begins to follow – The user does not move far to the left but stays in the right end gap and watches the actors content

R09 – 2 0092

User enters and moves along the back line to the right hand end – Position marker is in line with the user – Incorrect adaptation of the position marker to the left hand end – user follows the position marker to the left hand end – No new content window is shown

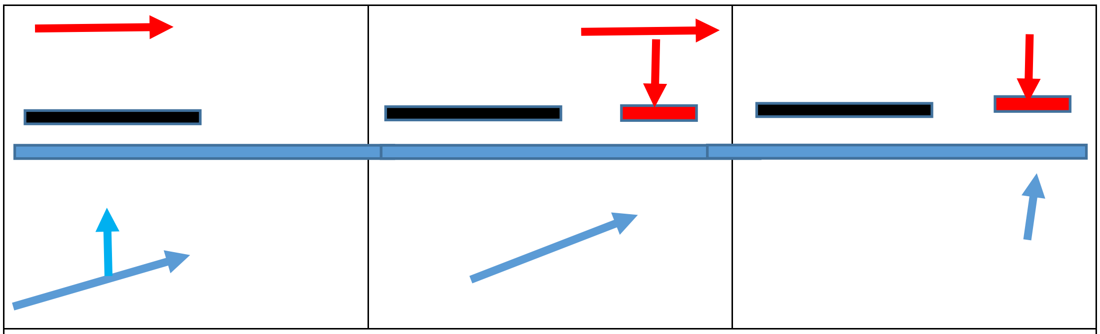


Fig. 2 – User enters the space and notices the position marker – The user attempts to form a window within the cluster of users – The position marker moves to the right hand side and a new window is formed – The user interacts with the new window.

R07 – 2 0088

User enters and moves towards the centre of the display – User slows as position marker moves from the left in line with the user – Position marker moves past the user to the right hand gap – user begins to move to the right hand gap and position maker – New content window is shown and user approaches the window

R10 – 2 0094

User enters and moves directly to the right hand end gap – User does not look at the position marker – User arrives at the right hand end and new content window is shown in front of the user

R20 – 2 0119

User enters and moves directly to the right hand end along the back row – Incorrect jumble of actor windows – Position marker moves to the right in line with the user – Position marker is in line with the user and a new content window is shown – User approaches the new content window

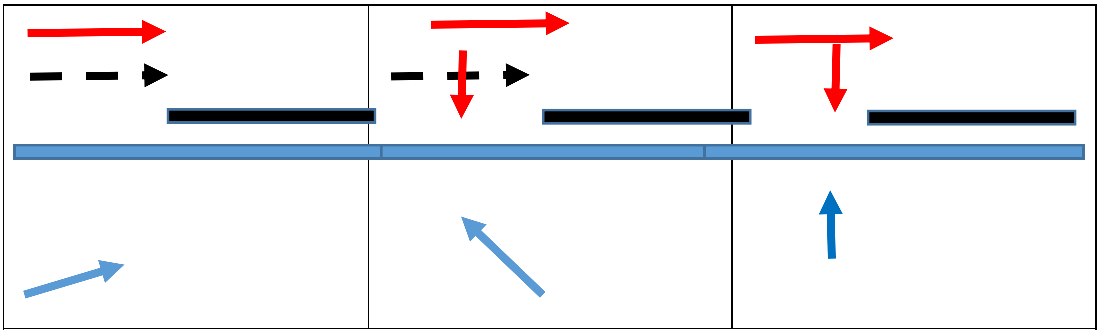


Fig. 3 – User enters and initial adaptation of right side of display – Position marker is still on the left hand side – User interacts with the position marker in the adapted gap on the left hand side – Position marker moves to the right – Tracking lost and new position marker shown at user position – User interacts with new position marker.

R13 – 2 0102

User enters – Confused jumble of actor windows – Adaptation of actor windows to the right – user approaches the adapted gap on the left – Position marker moves right past the user – user watches the position marker and begins to follow – New position marker is shown at the users location – user interacts with the new position marker

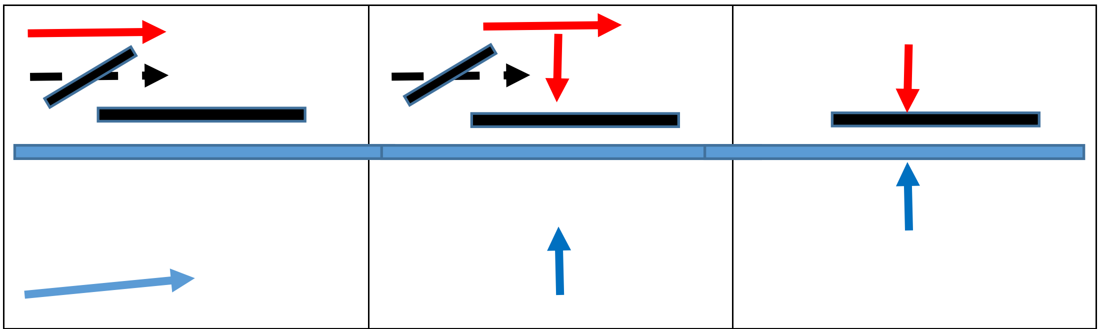


Fig. 4 – User enters and initial incorrect adaptation moves cluster to the centre right – User notices adaptation and engages with the position marker – No clear adaptation of the position marker – User pauses until no further adaptations – User joins the rear of the cluster in line with the position marker

R15 – 2 0107

User enters – Moves to the centre of the space – Incorrect adaptation of actor windows – Windows move in front of the user position – User pauses – User begins to move to the left hand adapted gap – Position marker is in line with the user – User notices marker and moves towards the centre of the display and the back of the group

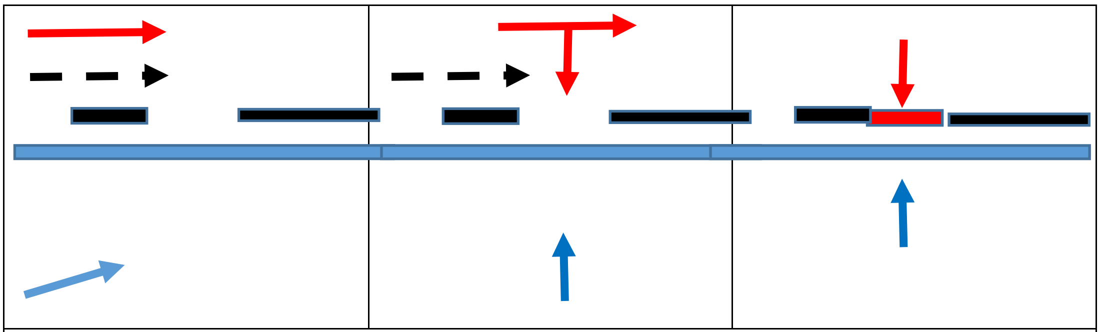


Fig. 5 – User enters and initial adaptation of three of the actors – user responds to the adaptation and approaches the display – User notices the position marker and interacts with the responsive state – New content window is shown and the user fully approaches

R18 – 2 0113

User enters – Early clear adaptation – Three actors move right and a gap is created on the left side – position marker is in the gap – User approaches the gap and position marker – New content window is shown and user interacts with window

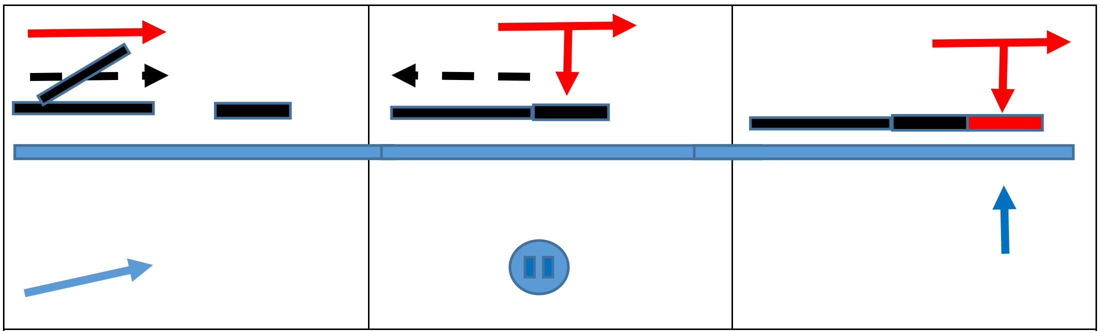


Fig. 6 – User enters and initial incorrect adaptation of actor four – User is moving right and notices movement – User pauses as correct adaptation moves actor back – User notices position marker and responds as it moves to the right – New window is shown and user approaches window

R22 – 2 0123

User enters and begins to move to the right – Incorrect adaptation of window four to the right – User pauses and watches the adaptation – Incorrect window moves back to the left to starting position – Position marker moves to the right past the user position and the adapting window – user begins to move to the right – New window is shown and user approaches the display – New window disappears and new position marker is shown

F3 Interaction Overview Tables

Behaviour Change Tables

Considering the distribution of top level Behaviours identified in the initial simplification analysis there are multiple secondary behaviours related to the system or user behaviour which lead to task completion. Within these cases where a user exhibits a preferred behaviour (1/2/3) during entry, there may be cases where a user also displays examples of less favourable actions relative to factors of the system. Identifying these factors leads to an informed understanding of the system design.

Considering the lower level descriptions of the interactions and branching shown in the interaction tables it is possible to consider how users entry can be influenced leading to lower level interactions and the overall distribution of these factors in relation to top level Behaviours.

Novice – Clustered

Novice – CLUSTERED – D							
Fig.	Factors of Entry	Entry Behaviour	Factors of Interaction	Interaction Behaviour	Factors of Engagement	Engagement Behaviour	Task
[1]	Small adaptation of a single actor. (7 users)	Gentle entry, medium pace. (7 users)	Position marker is moving from left to right.	User slows and begins to approach the new gap. (4 users)	Position Marker moves in to gap.	User identifies the marker and moves towards the gap. (4 users)	4.A
[2]			Adaptation moves to the left.	User pauses to watch the adaptation. Does not approach the gap. (2 users)	Position Marker moves in to gap.	User moves towards the adaptation. Does not engage with marker. (2 users)	2.F
[3]			Adaptation moves to the right to create a gap.	User pauses to watch the adaptation. (1 users)	Position Marker moves in to gap.	User identifies the marker and moves towards the gap. (5 users)	1.A
[4]	No adaptation (2 users)	Large confident entry towards the	No adaptation (1 user)	Large confident movement to the	Position marker moves in front of the user and	User engages with the window. (1 user)	1.A

		centre of the space. (4 users)		right of the display (1 user)	new window is shown.		
[5]			Single actor moves to the right (1 user)	User slows and begins to engage with the new gap (1 user)	Position marker in front of the user position moves to the right (1 user)	User follows the marker and leaves the gap (1 user)	1.A
[6]	Large adaptation. All actors move to the right. (2 user)	Large confident entry towards the centre of the space. (4 users)	Actors move back to the left. Position marker moves left to right. (1 user)	User Pauses and watches the adaptation. (1 user)	Marker moves to the right and window is shown.	User engages with the window. (1 user)	1.A
[7]			Actors are moving to the right. Position marker is moving to the right. (1 user)	User approaches the gap on the left side of the display. (1 user)	Position marker moves right and new window is shown. (1 user)	User observes marker and new window, makes correcting behaviour. (1 user)	1.A

1&3 = B2 = 5

2 = B6 = 2

Behaviour 2: 7 users – early clear adaptation of a single user

5 continue in Behaviour 2 – interact and follow the gap created – some interaction and confirmation from the marker

2 move to Behaviour 6 – observe the adaptation – secondary adaptation bring the user back in to the cluster – users do not identify the position marker – users move to the cluster

- Secondary adaptation draws the users attention back to the left hand side – moves them away from the position marker and new window

4 = B4 = 1

5 = B3 = 1

Behaviour 4: 2 users – large confident entry with no initial adaptation

1 user continues in Behaviour 4 - moves directly to the right hand side – content is then shown at their position after they have arrived

1 user moves to Behaviour 3 – small adaptation of a single actor in front of the user position – User engages with the adaptation and position marker to find the window

6 = B3 = 1

7 = B5 = 1

Behaviour 4: 2 users – Large confident entry with large adaptation

1 user moves to Behaviour 3 – Large adaptation right then left - movement of position marker to the right – User pauses and identifies a gap created

1 user moves to Behaviour 5 – Adaptation moves to the right and a gap is formed on the left – The user moves in to the gap – Marker moves to the right and a new window is shown – User corrects

Novice Clustered – D – Changing behaviours and contributing factors				
Fig.	Freq.	Entry	Result	Factors
1	4	2	2	
2	2	2	6	Secondary adaptation – Draws user towards the cluster – Difficult to identify the marker or location of new window
3	1	2	2	
4	1	4	4	
5	1	4	3	Small adaptation in front of user – User slows and a gap is created – User has the opportunity to identify factors
6	1	4	3	Secondary adaptation moves actors back – Position marker moves to the right user can engage
7	1	4	5	Gap is created on the left as user enters – No further adaptation – User approaches initial gap – User corrects behaviour

Novice – D – CLUSTERED							
Fig.	Factors of Entry	Entry Behaviour	Factors of Interaction	Interaction Behaviour	Factors of Engagement	Engagement Behaviour	Task
[1]	Jumbled adaptation of actors. No movement. (6 users)	User moves behind the cluster. (6 users)	Cluster remains on left. No movement. (6 users)	User makes decision to move to the right. (5 users)	Marker moves to the right. (5 users)	User responds to marker and engages with new window. (5 users)	5.A
[6]				User approaches rear of the cluster on the left.	Marker moves to the right and new window is shown.	User observes new window and moves to engage.	1.A

				(1 user)	(1 user)	(1 user)	
[2]	Large adaptation, actors split. Large gap in centre. (3 users)	User responds to adaptation and moves in to space. (3 users)	Marker does not move in to gap. (2 users)	User moves in to centre of space and aligns with gap. (2 users)	No further changes to display. (2 users)	User pauses in centre of gap. (2 users)	2.F
[5]			New marker shown in line with user. (1 user)	User does not respond to marker, stand in gap. (1 user)	Marker moves to right and new window shown. (1 user)	User stands in centre of gap. (1 user)	1.F
[3]	All actors move to the centre of the space. (3 users)	User slowly approaches centre of space. (3 users)	Secondary adaptation in centre of cluster. (3 users)	User slows and approaches the gap. (3 users)	Marker moves in line with the gap and window is shown. (2 users)	User moves in to the gap and engages with the window. (2 users)	2.A
[4]					Marker moves past the users to the right. (1 user)	User follows the marker to the right. (1 user)	1.A

1 = B2b = 5

6 = B5 = 1

Behaviour 2: 6 users – Jumbled adaptation of cluster – Users move behind the cluster

5 users continue in Behaviour 2 – The user observe the jumbled movement but continue past he cluster to the gap – there is some engagement with the position marker

1 user moves to Behaviour 5 – User moves to the rear of the cluster – Jumbled adaptation catches their attention – Position marker moves right and new window is shown – User corrects

2 = B2f = 2

5 = B6 = 1

Behaviour 2: 3 users – early large adaptation – user respond to adaptation

2 user stay in Behaviour 2 – Users have followed the adaptation and arrived in the gap in the centre of the display – There is no marker or window to engage with

1 user moves to Behaviour 6 – Early adaptation creating a gap in the centre – User moves to the gap – marker moves to the right and new window is shown on the right of the gap – user does not notice

3&4 = B2 = 3

Behaviour 2: 3 users – Early adaptation moves actors to the centre

3 users stay in Behaviour 2 – Secondary adaptation creates a gap and users approach – Position marker moves to the new location – user follow and engage with new window.

Novice D - Clustered – Changing behaviours and contributing factors				
Fig.	Freq.	Entry	Result	Factors
1	5	2	2b	There is a jumbled adaptation – This draws attention but does not help the user – Marker moves to the right and users follow
2	2	2	2f	There is a clear adaptation – User arrives in the gap – Window is not shown in the gap – User cannot identify the marker or window
3	2	2	2	
4	1	2	2	
5	1	2	6	Large adaptation and gap in centre – User responds to gap – Marker moves to the right – User does not follow
6	1	2	5	There is a jumbled adaptation – user moves towards the cluster – Marker moves to the right – User corrects from final layout

Repeat - Clustered

Repeat – CLUSTERED – D							
Fig.	Factors of Entry	Entry Behaviour	Factors of Interaction	Interaction Behaviour	Factors of Engagement	Engagement Behaviour	Task
[1]	Jumbled movement of actor windows. (8 users)	User moves towards centre of space. (8 users)	Marker moves to the right. (2 users)	User responds to marker as they are moving right. (2 users)	Marker arrives on right and new window is shown. (2 users)	User engages with window. (2 users)	2.A
[2]			Marker is in responsive state. (4 user)	User interacts with responsive marker. (4 user)	Marker moves with user and forms new window. (1 user)	User moves to the right and marker follows to form window. (1 user)	1.A
[4]					Marker moves to the right	User pauses and watches	1.A

					and new window is shown. (1 user)	marker move then goes to engage. (1 user)	
[3]					Window forms on left hand side. (1 user)	User moves to the right and marker does not follow. (1 user)	1.F
[9]			Marker is moving to the right. (1 user)	User moves to the right expecting marker. (1 user)	Marker moves right and window is shown. (1 user)	User adjusts position when window is shown. (1 user)	1.A
[10]			Marker moves behind the cluster. (1 user)	User slows and aligns to the marker. (1 user)	New window is shown behind cluster. (1 user)	User approaches reach of cluster to engage with window. (1 user)	1.A
[5]			Marker moves to right and window is shown. (1 user)	User moves to right and engages with window. (1 user)	Window disappears and marker moves to the left. (1 user)	User follows marker to the left. (1 user)	1.A
[6]	Large adaptatio n of all actors to the right. (3 users)	User moves in to centre of space. (3 user)	Marker is moving to the right behind actors. (3 users)	User moves to right hand side of display and pauses. (1 user)	Marker stops in centre of display and window shown. (1 user)	User moves to the right end and does not engage with window. (1 user)	1.F
[7]				User moves confidentl y to right hand end. (1 user)	Marker moves to the right and window is shown. (1 user)	User engages with new window. (1 user)	1.A
[8]				User confidentl y	Marker moves right and	User observes new	1.A

				approaches gap on left end. (1 user)	window is shown. (1 user)	window and moves right to engage. (1 user)	

1,2,4,5,10 = B1 = 6

9 = B1b = 1

3 = B1f = 1

Behaviour 1: 8 users – Jumbled adaptation of actors

Behaviour 1: 6 users – Some users slow but appear to engage with the marker and follow it before the window is shown – User identify meaning from marker

Behaviour 4: 1 user – Jumbled adaptation of actors – User quickly identifies the marker and moves to the right end – User adjusts position and follows the marker as they move

Behaviour 6: 1 user – Jumbled adaptation – User interacts with the marker – Marker begins to move to the right – User moves to the left hand gap

6 = B6 = 1

7,8 = B2c = 2

Behaviour 2: 3 users – User enter and there is a large adaptation in the centre of the display

1 user changes to B6 – User responds to the initial adaptation – User moves to the right hand end – Does not engage with the position marker or new window shown in the centre

2 users change to B2c – Both make confident pre-emptive moves based on the adaptation – One user is correct – the other has to make a correcting move – Initial confident move is defining factor.

Repeat Clustered – D – Changing behaviours and contributing factors				
Fig.	Freq.	Entry	Result	Factors
1	2	1	1	
2	1	1	1	
3	1	1	6	Jumbled adaptation – User interacts with the marker – Marker begins to lead right – User moves left
4	1	1	1	
5	1	1	1	

6	1	2	6	Large adaptation in centre – User responds – User moves to the right – Does not engage with marker or new window in centre
7	1	2	2c	
8	1	2	5(2c)	Large adaptation in centre – User responds – Confident approach to left gap – marker moves right – User corrects
9	1	1	4	User identifies marker – Pre-empts movement – As user gets to location begins to follow marker again
10	1	1	1	

Repeat – D - CLUSTERED							
Fig.	Factors of Entry	Entry Behaviour	Factors of Interaction	Interaction Behaviour	Factors of Engagement	Engagement Behaviour	Task
[1]	No adaptation. Marker moves to the right. (8 users)	User moves directly to the right side. (5 users)	Window is shown on the right side. (5 users)	User follows marker and engages with window. (5 users)	New marker is shown which moves left. (5 users)	User begins to follow marker but remains in gap. (5 users)	5.A
[2]		User interacts with marker and tries to form window. (3 users)	Marker moves to the right. (3 users)	User follows marker to the right. (3 users)	New window is shown in gap on right. (3 users)	User engages with new window. (3 users)	3.A
[3]	Large adaptation, all actors move right. (2 user)	User engages with gap. (1 user)	Marker moves in to the gap. (1 user)	User engages with marker. (1 user)	No window is shown. (1 user)	User engages with gap and marker. (1 user)	1.A
[4]		User moves behind the cluster. (1 user)	Marker moves to the right behind the cluster. (1 user)	User engages with the marker. (1 user)	New window is shown. Marker is behind the cluster. (1 user)	User continues to engage with the marker. (1 user)	1.A
[5]	Multiple adaptation on left hand end. (1 user)	User enters slowly and observes display. (1 user)	Marker moves to the right. (1 user)	User interacts with marker. (1 user)	Window is shown in centre gap. (1 user)	User engages with window but does not approach.	1.A

						(1 user)	
[6]	Multiple adaptations on right side. (1 user)	User enters slowly and observes display. (1 user)	Actors move back to left side. Marker moves to the right. (1 user)	User pauses to watch display. (1 user)	Marker moves to the right and window is shown. (1 user)	User moves to engage with the window. (1 user.)	1.A

1 – B3 – 5

2 – B1 – 3

Behaviour 4: 8 users – User initially enter with confidence, no adaptation

5 users change to Behaviour 3 – Users enter and move quickly to the right – Once at the gap the users identify the marker and begin to follow to find the window

3 users change to Behaviour 1 – User enter confidently but quickly identify the marker and begin to interact – When the marker moves the users follow to find a new window

3,4 – B2 – 2

Behaviour 2: 2 users – Early adaptation and users respond to gap and adaptation

Users stay in Behaviour 2 – Both users engage with the gap – Marker is shown in the gap – User engage with the marker and gap – Window is not clearly shown

5 – B1 – 1

Behaviour 1: Jumbled adaptation – user moves slowly and engages with marker – Uses marker to find new window

6 – B1 – 1

Behaviour 3: 1 user – User enters and there is a confused adaptation across the display – User pauses and investigates the display – User follows the marker as adaptation comes back.

Repeat D - Clustered – Changing behaviours and contributing factors				
Fig.	Freq.	Entry	Result	Factors
1	5	4	3	User enter confidently to the right hand gap – Once there users engage with factors of the display
2	3	4	1	User enter confidently towards the gap – During entry the user identify the marker and follow it to find the new window

3	1	2	2	
4	1	2	2	
5	1	1	1	
6	1	3	1	Upon entry there is a jumbled adaptation – User waits while adaptation is confused – User engages and follows position marker

Novice – Distributed

Novice – DISTRIBUTED - C							
Fig.	Factors of Entry	Entry Behaviour	Factors of Interaction	Interaction Behaviour	Factors of Engagement	Engagement Behaviour	Task
[1]	Large adaptation in centre of display. (6 users)	Moves towards centre of space. (6 users)	Position marker moves in to gap. (5 users)	User responds to marker. (5 users)	New window is shown in gap. (5 users)	User engages with window. (5 users)	5.A
[5]			Position marker moves behind group on left. (1 user)	User pauses on left to observe the gap. (1 user)	New window is shown behind user on left. (1 user)	User stands on left. Cannot identify point to interact. (1 user)	1.F
[2]	Adaptation on right hand end. (3 users)	User moves slowly towards centre. (3 users)	Small adaptation on right hand end. Marker moves to the right. (2 users)	User moves to the right. (2 users)	Marker is moving to the right and new window is shown in the gap. (2 users)	User responds to the gap and engages with the marker and new window. (2 users)	2.A
[6]			Secondary adaptation on left end. (1 user)	User does not engage with any adaptation. (1 user)	Marker moves in to left gap and window is shown. (1 user)	User does not engage with display. Moves to the right. (1 user)	1.F
[3]	Adaptation on left hand end. (2 user)	User approaches the gap. (2 user)	Marker moves in to the gap. (1 user)	User approaches the gap and engages	New window is shown in the gap. (1 user)	User engages with the new window.	1.A

				with the marker. (1 user)		(1 user)	
[4]			Secondary adaptation on right hand end. (1 user)	User pauses in front of first gap. (1 user)	Marker moves past user and new window is shown in right gap. (1 user)	User moves left and engages with left hand gap. (1 user)	1.F
[7]	Windows cluster in centre. (1 user)	User moves towards the centre behind the cluster. (1 user)	Secondary adaptation in centre of cluster. (1 user)	User responds to adaptation and approaches gap. (1 user)	Marker moves in to gap and window shown. (1 user)	User engages with gap and new window. (1 user)	1.A

1 – B2 - 5

5 – B2f – 1

Behaviour 2 – 6 users – Large adaptation with user responding to movement

5 users stay in B2 – Large gap created in adaptation – User identifies marker and window appears in gap – User approaches and interacts

1 user in B2f – User follows adaptation – Marker is behind an actor – Window is hidden behind actor - User cannot identify where to interact – No further adaptation

2 – B2 - 2

6 – B6 – 1

Behaviour 3: 3 users – User enters with small adaptation on right hand end – user moves in to centre

2 users to Behaviour 2: adaptation continues on right hand end – User is moving in that direction – Window moves in to gap and user responds

1 user moves to Behaviour 6: User enters the space – second adaptation on left hand end – User does not engage with any adaptation

3 – B2 - 1

4 – B6 - 1

Behaviour 2: Initial adaptation on left hand end – User approaches the gap

1 user stays in Behaviour 2 – Marker moves in to gap and user engages – New window shown

1 user moves to Behaviour 6 – Secondary adaptation on right – Marker moves past user – User moves towards the (first) left hand gap

7 – B3 - 1

Behaviour 3: Windows cluster and user observes the cluster – Gap formed in cluster – New window

Novice Distributed – C – Changing behaviours and contributing factors				
Fig.	Freq.	Entry	Result	Factors
1	5	2	2	
2	2	3	2	Small adaptation as user enters – User is moving towards adaptation – Adaptation continues and user engages
3	1	2	2	
4	1	2	6	Secondary adaptation – Marker moves past user – User does not respond – Engages with initial adaptation
5	1	2	2f	User follows adaptation and marker – Window is hidden – user cannot identify the point of interaction
6	1	3	6	Initial small adaptation – Secondary adaptation – User does not engage with any aspect of adaptation
7	1	3	3	

Novice – C - DISTRIBUTED							
Fig.	Factors of Entry	Entry Behaviour	Factors of Interaction	Interaction Behaviour	Factors of Engagement	Engagement Behaviour	Task
[1]	Large adaptation in centre of display. (5 users)	Moves towards centre of space. (4 users)	Position marker moves in to gap. (4 users)	User responds to marker. (4 users)	New window is shown in gap. (4 users)	User engages with window. (4 users)	4.A
[6]	Adaptation in centre of display, secondary on left of display. (1 user)	User responds to secondary adaptation. (1 user)	Marker moves past user position. (1 user)	User engages with second adaptation gap. (1 user)	Marker and window are shown in first gap. (1 user)	User responds to marker and new window. (1 user)	1.A
[2]	Clear adaptation on right end of display. (4 users)	User is confidently approaching right hand end. (2 users)	Position marker follows the user. (2 users)	User is moving right towards the gap. (2 users)	Clear gap on right. Marker moves to the gap and window shown. (2 users)	User arrives in gap and engages with new window. (2 users)	2.A
[5]		User interacts with	Secondary adaptation	User interacts with	Marker arrives on right and	User follows marker and	1.A

		position marker. (1 user)	n on left. Marker is moving right. (1 user)	position marker. (1 user)	new window is shown. (1 user)	engages with new window. (1 user)	
[7]		User confidently approaches left hand end. (1 user)	Secondary adaptation on left end. (1 user)	User continues to interact with content already shown. (1 user)	Marker moves towards new left gap and window shown. (1 user)	User does not engage with new gap, marker or window. (1 user)	1.F
[3]	Small adaptation on the left side. (2 users)	Medium approach towards adaptation. (2 users)	Position marker moves past gap. (1 user)	User does not respond to marker. Engages with gap. (1 user)	Marker moves to the right and new window is shown. (1 user)	User engages with first adaptation gap. (1 user)	1.F
[4]			Secondary adaptation on right. Marker moves past gap. (1 user)	User responds to first adaptation. (1 user)	Marker moves towards second gap. (1 user)	User changes minds and approaches first gap. (1 user)	1.F

1 – B1 – 4

Behaviour 2: User responds to initial adaptation in centre of display

During approach User engages with position marker – Follows marker to window

6 – B5 – 1

Behaviour 2: User responds to initial adaptation

Secondary adaptation draws user away – Marker moves past user position – User is engaging with second adaptation – User looks across display and corrects

2 – B2c – 2

5 – B1 - 1

7 – B4 - 1

Behaviour 2c – User confidently enters the space moving to the right – Clear adaptation on the right – User arrives in the gap as window is shown

Behaviour 1: User identifies position marker – Secondary adaptation on left – User follows marker to the right – user arrives at window

Behaviour 4: User confidently approaches left hand end – Secondary adaptation on left – Marker moves to location – User interacts with existing windows

3 – B6 - 1

4 – B6 – 1

Behaviour 3: Small adaptation with medium entry – Users initially respond to adaptation

Secondary adaptation – Marker moves past user position – User engages with first adaptation

Novice C - Distributed – Changing behaviours and contributing factors				
Fig.	Freq.	Entry	Result	Factors
1	4	2	1	Initial adaptation draws user to centre of space – Position marker is easy to engage with from user position
2	2	2c	2c	
3	1	3	6	User responds to initial adaptation – Secondary adaptation - Marker moves past location – user engages with first adaptation
4	1	3	6	User responds to initial adaptation – Secondary adaptation - Marker moves past location – user engages with first adaptation
5	1	1	1	
6	1	2	5	Secondary adaptation draws users attention – Marker moves away as user is responding to secondary – User identifies and corrects
7	1	4	4	

Repeat – Distributed

Repeat – DISTRIBUTED - C							
Fig.	Factors of Entry	Entry Behaviour	Factors of Interaction	Interaction Behaviour	Factors of Engagement	Engagement Behaviour	Task
[1]	Small adaptation on right hand side. (5 users)	User moves towards the right hand side.	Marker is moving to the right in line	User engages with the marker. (3 users)	New window is shown in gap. (3 users)	User is in line with window but does	3.A

		(4 users)	with the user. (4 users)			not approach. (3 users)	
[8]				User slows and observes marker. (1 user)	Marker arrives in gap and window is shown. (1 user)	User moves slowly right but does not approach or engage. (1 user)	1.A
[7]		User moves slowly in to space. (1 user)	Marker is in responsive state on left side. (1 user)	User stands in line with marker. (1 user)	New window is shown in line with user. (1 user)	User engages with window but does not approach. (1 user)	1.A
[2]	Small adaptation on left hand side. (3 users)	User aligns to gap and interacts with marker. (3 users)	Window is shown in gap. (3 users)	User stands in line with window. (3 users)	No change to layout. (3 users)	User does not approach any closer. (3 users)	3.A
[4]	Large adaptation on left hand side. (2 user)	User aligns to gap and interacts with marker. (2 users)	Window is shown in gap. (1 users)	User stands in line with window. (1 users)	No change to layout. (1 users)	User does not approach any closer. (1 users)	1.A
[5]			Marker moves to right hand side. (1 user)	User moves towards the left side. (1 user)	Window is shown on right side. (1 user)	User engages with left hand gap. (1 user)	1.F
[3]	Multiple adaptations on right hand end. (1 user)	User enters and confidently moves to the right. (1 user)	Marker moves to the right in line with centre gap. (1 user)	User moves confidently to right of display. (1 user)	Window is shown in centre gap. (1 user)	User moves to right hand gap and does not engage with window. (1 user)	1.F
[6]	Multiple adaptations on left	User enters slowly	Marker moves to the right.	User engages with	Marker moves to the right	User engages	1.F

	and centre. (1 user)	and observes display. (1 user)	(1 user)	marker but remains on left. (1 user)	and window is shown. (1 user)	with gap on left side. (1 user)	

1 – B1 - 3

8 – B1 - 1

7 – B1 - 1

Behaviour 2: Small adaptation on right hand side – User is moving to the right

User engage with the marker while moving in to or through the space

2 – B2 – 3

Behaviour 2: Adaptation on left hand side as user enters

User aligns to gap and window is shown

4 – B2 - 1

5 – B2f - 1

Behaviour 2: Adaptation on left hand side – user engages with gap

User aligns to gap and new window is shown

User aligns to gap – Marker moves to the right – User stays aligned to gap – User does not identify new window shown on right hand side

3 – B4f – 1

Behaviour 2c: User enters confidently and moves to right hand side – Multiple adaptations on right hand end of display – Marker moves in to centre – User is at right gap – Does not identify window

6 – B2f – 1

Behaviour 2: User enters slowly with multiple adaptation on left end – Marker moves to the right and user notices – User stays in left hand gap

Repeat Distributed – C – Changing behaviours and contributing factors				
Fig.	Freq.	Entry	Result	Factors
1	3	1	1	
2	3	2	2	
3	1	2c	4f	User moves confidently to right side – Multiple adaptation on centre/right – Marker moves to centre gap – User stays in right gap
4	1	2	2	
5	1	2	2f	Adaptation on left – User aligns to gap – Marker moves to the right – User stays in gap – User does not identify window shown on right

6	1	2	2f	User responds to initial adaptation – User identifies marker – Marker moves right - User stays at adaptation
7	1	1	1	
8	1	1	1	

Repeat – C - DISTRIBUTED							
Fig.	Factors of Entry	Entry Behaviour	Factors of Interaction	Interaction Behaviour	Factors of Engagement	Engagement Behaviour	Task
[1]	Small adaptation in centre of display. (4 users)	User moves in to space and engages with position marker. (4 users)	Marker moves in to the gap. (4 users)	User slows and observes marker moves in to gap. (3 users)	Window is formed in gap. (3 users)	User moves to engage with new window. (3 users)	3.A
[3]				User moves to the left hand end. (1 user)	New window is shown in centre gap. (1 user)	User stands on left hand end. (1 user)	1.F
[2]	Small adaptation on right hand end. 6 users)	User enters and observes adaptation. (5 users)	Marker moves to the right. (2 users)	User approaches the gap ahead of marker. (2 users)	Marker arrives in gap and window is shown. (2 users)	User engages with new window. (2 users)	2.A
[4]		User moves directly to the right hand end. (1 user)	Marker is moving to the right. (1 user)	User moves confidently to the right end. (1 user)	Marker arrives in the gap and window is shown. (1 user)	User engages with the new window (1 user)	1.A
[5]			Secondary adaptation on the left. (2 user)	User engages with the second gap. (2 user)	Marker moves to the right and window is shown in the first gap on the right. (2 user)	User observes the marker and new window and moves to engage. (1 user)	1.A
[6]						User stays in the left hand gap and does	1.F

						not see new window. (1 user)	
[7]			Secondary adaptation moves actors back to starting places. (1 user)	User makes decision to move to the left. (1 user)	Marker moves to the right and window is shown. (1 user)	User observes new window and moves over to engage. (1 user)	1.A
[8]	Adaptation on left and gap created. (1 user)	User moves in line with gap. (1 user)	Secondary adaptation in centre of display. (1 user)	User moves in line with new gap. (1 user)	Marker moves in to gap and window is shown. (1 user)	User waits for marker and moves to engage with window. (1 user)	1.A

1 – B1 - 3

3 – B6 – 1

Behaviour 1: Small adaptation in centre – User identifies marker

6 – Marker moves to the centre gap – User moves to the left end – Window is shown – User stays

2 – B2c - 2

4 – B2c - 1

5 – B5 - 1

6 – B6 - 1

7 – B5 – 1

Behaviour 2: Adaptation at the right hand end – User enter slowly and observe adaptation

2 - B2c – Marker moves to the right – user moves confidently towards the gap – Marker arrives and window is shown

4 – B2c – User enters and moves confidently to the right hand end

5 – B5 – Secondary adaptation – User moves to the new gap on left – marker moves to the right – user identifies marker and new window – User moves to correct

6 – B6 – User confidently approaches the left hand end – Does not notice the marker or new window

7 – B5 – Secondary adaptation moves actors left to starting places – User decides to move left – Marker moves to the right – User identifies marker and new window and corrects

8 – B1 – 1

B2 – User enters and adaptation on left side – Secondary adaptation in centre – Marker moves to the right – User moves in to gap and waits for marker – New window is shown

Repeat C - Distributed – Changing behaviours and contributing factors				
Fig.	Freq.	Entry	Result	Factors
1	3	1	1	
2	2	2	2c	Small adaptation on right end – Marker moves right – User moves past the marker to the gap – Window is shown – User engages
3	1	1	6	Adaptation in centre – User identifies marker – Marker moves towards centre – User moves to the left
4	1	2	2c	Small adaptation on right end – User moves directly to right end
5	1	2	5	Secondary adaptation – User moves to new gap – Marker moves right – User identifies marker and new window – User corrects
6	1	2	6	User confidently approaches left hand end – Does not notice marker or new window
7	1	2	5	Secondary adaptation moves actors left – User moves to left gap – notices marker and new window – User corrects
8	1	2	1	User follows initial adaptation – Second adaptation - Marker moves towards new gap – User responds to marker and second gap

Combined Table

Clustered – Changing behaviours and contributing factors			
Entry	Result	Freq.	Factor
1	4	1	(R/F) User identifies marker – Pre-empts movement – As user gets to location begins to follow marker again
1	6	1	(R/F) Jumbled adaptation – User interacts with the marker – Marker begins to lead right – User moves left
2	2b	5	(N/S) There is a jumbled adaptation – This draws attention but does not help the user – Marker moves to the right and users follow

2	2f	2	(N/S) There is a clear adaptation – User arrives in the gap – Window is not shown in the gap – User cannot identify the marker or window
2	5	2	(N/S) There is a jumbled adaptation – User moves towards the cluster – Marker moves to the right – User corrects from final layout (R/F) (2c) Large adaptation in centre – User responds – Confident approach to left gap – marker moves right – User corrects
2	6	4	(N/F) Secondary adaptation – Draws user towards the cluster – Difficult to identify the marker or location of new window (N/S) Large adaptation and gap in centre – User responds to gap – Marker moves to the right – User does not follow (R/F) Large adaptation in centre – User responds – User moves to the right – Does not engage with marker or new window in centre
3	1	1	(R/S) Upon entry there is a jumbled adaptation – User waits while adaptation is confused – User engages and follows position marker
4	1	3	(R/S) User enter confidently towards the gap – During entry the user identify the marker and follow it to find the new window
4	3	7	(N/F) Small adaptation in front of user – User slows and a gap is created – User has the opportunity to identify factors (N/F) Secondary adaptation moves actors back – Position marker moves to the right user can engage (R/S) User enter confidently to the right hand gap – Once there users engage with factors of the display
4	5	1	(N/F) Gap is created on the left as user enters – No further adaptation – User approaches initial gap – User corrects behaviour

Distributed – Changing behaviours and contributing factors			
Entry	Result	Freq.	Factor
1	6	1	(R/S) Adaptation in centre – User identifies marker – Marker moves towards centre – User moves to the left
2	1	5	(N/S) Initial adaptation draws user to centre of space – Position marker is easy to engage with from user position (R/S) User follows initial adaptation – Second adaptation - Marker moves towards new gap – User responds to marker and second gap

2	2c	3	(R/S) Small adaptation on right end – Marker moves right – User moves past the marker to the gap – Window is shown – User engages (R/S) Small adaptation on right end – User moves directly to right end
2	2f	3	(N/F) User follows adaptation and marker – Window is hidden – user cannot identify the point of interaction (R/F) Adaptation on left – User aligns to gap – Marker moves to the right – User stays in gap – User does not identify window shown on right (R/F) User responds to initial adaptation – User identifies marker – Marker moves right - User stays at adaptation
2c	4f	1	(R/F) User moves confidently to right side – Multiple adaptation on centre/right – Marker moves to centre gap – User stays in right gap
2	5	3	(N/S) Secondary adaptation draws users attention – Marker moves away as user is responding to secondary – User identifies and corrects (R/S) Secondary adaptation – User moves to new gap – Marker moves right – User identifies marker and new window – User corrects (R/S) Secondary adaptation moves actors left – User moves to left gap – notices marker and new window – User corrects
2	6	2	(N/F) Secondary adaptation – Marker moves past user – User does not respond – Engages with initial adaptation (R/S) User confidently approaches left hand end – Does not notice marker or new window
3	2	2	(N/F) Small adaptation as user enters – User is moving towards adaptation – Adaptation continues and user engages
3	6	3	(N/F) Initial small adaptation – Secondary adaptation – User does not engage with any aspect of adaptation (N/S) User responds to initial adaptation – Secondary adaptation - Marker moves past location – user engages with first adaptation

These factors can now be separated in to two broad aspects; Positive and Negative effects on outcome relative to, either User and System. This can be further considered in relation to Novice vs. repeat users, however, this is a secondary consideration once the initial groupings are considered.

Clustered – User factors

Positive influences

Clustered – Users Factors – Positive Influence			
Entry	Result	Freq.	Factor

There were several changes in behaviour which were identified as user decision which had a positive influence on the outcome of the task, however, the initial cause of the issue was related to the system function or was caused by an initial user decision. As these are factors of correcting behaviour the entries have been placed in to the appropriate tables below.

Negative influences

Clustered – Users Factors – Negative Influence			
Entry	Result	Freq.	Factor
1	4	1	(R) User identifies marker – Pre-empts movement – As user gets to location begins to follow marker again
1	6	1	(R) Jumbled adaptation – User interacts with the marker – Marker begins to lead right – User moves left
2	5	1	(R) (2c) Large adaptation in centre – User responds – Confident approach to left gap – marker moves right – User corrects
2	6	1	(R) Large adaptation in centre – User responds – User moves to the right – Does not engage with marker or new window in centre

In all of these cases the users initially engage with the adaptation and are influenced in their approach and decision making. The major limitations in achieving the task can be identified;

- (N/R) user initially interacts with the marker but does not identify the meaning when it transitions to a leading state. There is no clear adaptation for the marker to support a change in position and the interactivity or feedback is not enough to support a change.
- (N/R) user does not fully engage with the meaning of the marker in relation to their own experience, instead they draw meaning form the adaptation. When there is additional movement from the marker the user does not identify or follow. The user identifies their window when there is nothing shown at their location, but there is another window shown.
- The (R) user pre-empts the meaning of the adaptation and position marker to confidently move directly to the location. As they arrive they re-engage with the marker to identify the interaction location. The users confidence causes them to separate from the leading condition, which did not limit the interaction, but limits the systems functionality.

Clustered – System factors

Positive influences

Clustered – System Factors – Positive Influence			
Entry	Result	Freq.	Factor
3	1	1	(R) Upon entry there is a jumbled adaptation – User waits while adaptation is confused – User engages and follows position marker

4	1	3	(R) User enter confidently towards the gap – During entry the user identify the marker and follow it to find the new window
4	3	7	(N) Small adaptation in front of user – User slows and a gap is created – User has the opportunity to identify factors (N) Secondary adaptation moves actors back – Position marker moves to the right user can engage (R) User enter confidently to the right hand gap – Once there users engage with factors of the display

In all cases the users engage with the layout of the display but the individual behaviour influences how users are able to learn;

- There are several cases of users entering confidently, either relative to the current layout or due to a small adaptation. The significant difference between these users is their experience in understanding the system relative to their confident approach;
    - (R) user is able to identify the position marker as they are entering and uses it to orientate to the correct location.
    - (R) user confidently approaches the gap and refines their final approach as the window is shown but the interaction is less refined.
    - (N) users enter confidently but slows their entry as adaptation takes place. The uncertainty in changes of the display cause the users to assess the display to identify meaning of the adaptation and potential feedback.
- The alternative case sees a jumbled adaptation cause a (R) user to slow and observe the display to draw meaning. During this inspection the user identifies the position marker and infers the leading intention to the location.

Negative influences

Clustered – System Factors – Negative Influence			
Entry	Result	Freq.	Factor
2	2b	5	(N) There is a jumbled adaptation – This draws attention but does not help the user – Marker moves to the right and users follow
2	2f	2	(N) There is a clear adaptation – User arrives in the gap – Window is not shown in the gap – User cannot identify the marker or window
2	5	1	(R) (2c) Large adaptation in centre – User responds – Confident approach to left gap – marker moves right – User corrects
2	6	3	(N) Secondary adaptation – Draws user towards the cluster – Difficult to identify the marker or location of new window (N) Large adaptation and gap in centre – User responds to gap – Marker moves to the right – User does not follow
4	5	1	(N) Gap is created on the left as user enters – No further adaptation – User approaches initial gap – User corrects behaviour

In all cases users initially engage with the display and adaptation, however, there are a range of influencing factors of the display which influence the outcome of the interaction;

- (N) user enters confidently as there is a gap created in line with their approach. The users initial approach is reinforced by the gap being shown, however, the user maintains an awareness of the space and is able to identify a correcting behaviour.
- Considering how users respond to adaptation during entry there were several factors which influenced how this lead to convoluted task completion;
    - (R) user exhibited a high confidence in their early decision making based on the adaptation. As the adaptation was partially complete the users decision resulted in an incorrect approach and correcting behaviour as the adaptation continued.
- The remainder of the (N) users identified a jumbled adaptation as a point of interest and began to engage, this had two repercussion;
    - Two (N) users observed the jumbled adaptations and were able to identify the marker and new window moving past the cluster and complete the task.
    - (N) user identified the jumbled adaptation but not the movement of the marker or window. This user corrected behaviour based on the final layout.
    - 3 (N) users moved to engage with the jumbled adaptation and the cluster. From this position it was not possible to identify the marker or the final layout of the display to be able to correct and locate the new window.

Clustered configuration – Discussion of influencing factors

While it has been possible to separate the leading factors of User or System factors which influence the interaction, it is clear that the two are extremely closely linked. Where there are instances of extremely similar entry and User / System factors, the outcome of the interactions can vary greatly based on relative timing and placement of these factors relative to on-going behaviour. Further, the apparent experience of the user with aspects of the system can influence how these factors are perceived, or how a users' decision making can inform the unfolding interactions.

The major contributing factor of this configuration appears to be the lack of feedback offered by adaptation and the gap which is already shown. As there is no clear adaptation and change in layout for the user to identify, there is a potential for users to engage with the cluster or incorrect / jumbled adaptation of the cluster. Adaptation of the cluster can draw users attention, which can aid in identifying factors of the system, but can also lead to negative reinforcement if the adaptation is significant enough.

It is also harder for user to identify and engage with the position marker in the correct manner as it does not directly relate to an aspect of the display or expected user experience. Where a user is engaging with an adaptation the position marker can be ignored as the user decision is reinforced by incorrect adaptation. However, jumbled adaptation can also draw the user attention to help identify the marker which can then lead user to the correct location. This is where timing and position of adaptation must be considered. Where there is an adaptation near a user it is likely to be linked to their current decision making. If this supports their movement then it is likely to reinforce their decision and prevent further understanding. However, it is possible to user these factors to draw attention to help identify the position marker for further leading and display identification.

Distributed – User factors

Positive influences

Distributed – Users Factors – Positive Influence			
Entry	Result	Freq.	Factor

There were no positive influences of user behaviour identified in the Distributed configuration which were not correcting behaviours by users. As there was already an error either due to user or system behaviour, correcting actions are not considered here.

Negative influences

Distributed – Users Factors – Negative Influence			
Entry	Result	Freq.	Factor
2	5	1	(R) Secondary adaptation moves actors left – User moves to left gap – notices marker and new window – User corrects
2	6	2	(N) Secondary adaptation – Marker moves past user – User does not respond – Engages with initial adaptation (R) User confidently approaches left hand end – Does not notice marker or new window
3	6	1	(N) Initial small adaptation – Secondary adaptation – User does not engage with any aspect of adaptation

All users are initially engaging with aspects of adaptation, with an influencing factor of on-going secondary adaptation but the results of user decision influence the outcome of the interaction;

- Continuous engagement with the adaptation and secondary adaptations limit the ability of users to fully identify the meaning of the position marker.
    - (R) user follows all adaptations of the display but does not identify the relation to the leading marker. The user maintains an awareness of the display and corrects when a window is not shown in the new gap.
    - (N) user follows the secondary adaptation but does not maintain an awareness of the display. The users does not make a correcting action.
- A lack of awareness or overconfidence in decision making more greatly effect how users move through the space;
    - (N) user observes the initial adaptation but moves freely with no response to the initial or secondary change.
    - (R) immediately and confidently responds to the initial adaptation but does not identify or engage with secondary. The user has not identified their relation to the position marker and commits to their decision.

Distributed – System factors

Positive influences

Distributed – System Factors – Positive Influence

Entry	Result	Freq.	Factor
2	1	5	(N) Initial adaptation draws user to centre of space – Position marker is easy to engage with from user position (R) User follows initial adaptation – Second adaptation - Marker moves towards new gap – User responds to marker and second gap
2	2c	3	(R) Small adaptation on right end – Marker moves right – User moves past the marker to the gap – Window is shown – User engages (R) Small adaptation on right end – User moves directly to right end
3	2	2	(N) Small adaptation as user enters – User is moving towards adaptation – Adaptation continues and user engages

The influence of adaptation and ability for users to infer meaning can either support further engagement and feedback or solidify meaning of the expected behaviour;

- (N/R) approach the initial adaptation and identify the position marker. This is then followed closely to the final location.
- (N) slow measured entry is further reinforced as the user approaches the new gap.
- (R) identify the initial adaptation and approach directly with no further regard for the display or factors of adaptation.

Negative influences

Distributed – System Factors – Negative Influence			
Entry	Result	Freq.	Factor
2	2f	3	(N) User follows adaptation and marker – Window is hidden – user cannot identify the point of interaction (R) Adaptation on left – User aligns to gap – Marker moves to the right – User stays in gap – User does not identify window shown on right (R) User responds to initial adaptation – User identifies marker – Marker moves right - User stays at adaptation
2c	4f	1	(R) User moves confidently to right side – Multiple adaptation on centre/right – Marker moves to centre gap – User stays in right gap
2	5	2	(N) Secondary adaptation draws users attention – Marker moves away as user is responding to secondary – User identifies and corrects (R) Secondary adaptation – User moves to new gap – Marker moves right – User identifies marker and new window – User corrects
3	6	3	(N) User responds to initial adaptation – Secondary adaptation - Marker moves past location – user engages with first adaptation

The degree of influence of the adaptation can in turn limit the corrections which can be made either by the user or secondary adaptation;

- (R) respond to initial adaptation and commits to the location. No engagement with the maker and unable to identify correcting action from the position.
    - (R) identifies marker but not the relationship, commits to a location and is unable to identify correcting behaviour.
- (R) Initial adaptation leads user to position, but small secondary adaptations are ignored. User does not identify position marker or relation to secondary adaptations as the first indicated a correct location.
- (N/R) users engage with secondary adaptation but also engage with the behaviour of the marker. As the user responds to secondary adaptation the marker moves away and the user performs correcting behaviour.
- (N) the user engages with secondary adaptation and marker, but marker moves away and user moves towards the first adaptation. Multiple adaptations have separated the meaning of the marker and the relation to the user. Confusion and an initial influencing factor lead the user to make their own decision.

Distributed configuration – Discussion of influencing factors

The initial adaptation has a strong impact upon users' entry decision making. The distributed configuration does not offer a clear initial point of interest or interaction for new users, either novice or repeat, in the way that Clustered appears to. So any small adaptation will draw the users' attention, however, this can have a dual impact where users no longer engage with the display or on-going factors, such as secondary adaptations.

The difficultly of secondary adaptations in the distributed configuration appeared to be the density of users at the display. A user was able to identify the meaning of early adaptations during approach, but once they were at the display it was more difficult to identify meaning from secondary. The ability for users' to engage with the position marker was also apparent once a users' was at the display. The position marker can still be effective in recovering understanding, however, the marker must be shown in a relevant position, such as close to the initial adaptation.

Differences in Clustered and Distributed Configurations in changing behaviour

The distribution of these factors between both configurations seem extremely similar for both cases, where there were 46 users in each case.

Clustered - 0/4/11/12 (27) – 27/46 = 59%

Distributed - 0/4/10/9 (23) – 23/46 = 50%

The clustered configuration does not offer a clear point of adaptation upon entry as the distributed case does. This can lead user to engaging with initial incorrect / jumbled adaptation on the clustered display, but also then identifying the position marker as a secondary factor in understanding the display. With the distributed condition the initial adaptation tends to leads users directly to a location, where it is then challenging for users to identify secondary adaptations, or the relevance of the position marker due to the distributed users. Both cases showed the influence of localised adaptation when a user is initially approaching, such that an incorrect adaptation when a user approaches can infer a correct decision, leading to the user not be able to correct.

Where the clustered configuration has a clear separation between on-going users and the free space, this leads users to being more prone to identifying the meaning of the position marker, or being able to correct when the adaptation completes. With the distributed case there is less ability for users to identify the marker or correcting behaviour once they have made an initial decision. While initial adaptation is easier to identify in the distributed case, this is a limiting factor in further engagement or understanding.

In both cases the position and timing of adaptations can have a significant influence on the users' decision making. If adaptations take place close to a user there is a stronger influence on their decision making and supporting understanding but with a reduced awareness of the display.

All of these factors are subsumed under the initial entry approach of the users and their confidence / awareness of the display. Confident entry, either based on prior understanding or initial feedback from adaptation will alter how a user gains further feedback or responds to changes of the display. In cases where a user has identified a point of feedback and interaction, any further adaptations or changes of the position marker may not be related to the users behaviour as they have already established enough information to have made a decision and to then stick with it. In these cases it should be considered how further changes or supporting information can be delivered to the user.

Transition from smooth system engagement to staggered or no engagement

**How do users transfer from 1/3 – 4/6 Behaviours

**There are small factors which influence small changes in behaviours 1-3, but these ultimately result in achieving the task

**What are the differences in Novice / Repeat users entry conditions vs. final numbers of behaviours

Considering the behaviours of users (1-6), the first 3 consider how users ideally engage with factors of the display and feedback in achieving the task, such that there is a clear relationship to these factors it eh user achieving the task. Behaviours 4-6 consider user centric decision making and miss-interpretation of the display, such that the user either does not engage with the display in achieving or failing the task, or is required to make a significant correction based on the final layout. As the investigation is aimed at identifying the role of the display in aiding the user, any transition from states 1-3 to 4-6 should be carefully considered, as the user has initially engaged in a manner which should lead to a positive interaction.

Clustered

Clustered – Negative transition factors – 1/3 – 4-6			
Entry	Result	Freq.	Factor
User Factors			
1	4	1	(R) User identifies marker – Pre-empts movement – As user gets to location begins to follow marker again
1	6	1	(R) Jumbled adaptation – User interacts with the marker – Marker begins to lead right – User moves left
2	5	2	(N) There is a jumbled adaptation – User moves towards the cluster – Marker moves to the right – User corrects from final layout

			(R) (2c) Large adaptation in centre – User responds – Confident approach to left gap – marker moves right – User corrects
2	6	1	(R) Large adaptation in centre – User responds – User moves to the right – Does not engage with marker or new window in centre
Display Factors			
2	5	2	(N) There is a jumbled adaptation – User moves towards the cluster – Marker moves to the right – User corrects from final layout (R) (2c) Large adaptation in centre – User responds – Confident approach to left gap – marker moves right – User corrects
2	6	3	(N) Secondary adaptation – Draws user towards the cluster – Difficult to identify the marker or location of new window (N) Large adaptation and gap in centre – User responds to gap – Marker moves to the right – User does not follow

(5/5) – All negative user factors were significant transitions from 1/3 – 4/6 - 5/46 = 11%

User decision making – Either over confident or responding to the initial adaptation and not engaging with the system any further to identify further meaning from secondary adaptation or the relative location and relationship of the position marker.

(5/13) – Less than half were significant transitions from 1/3 – 4/6 – 5/46 = 11%

Display errors – Initial adaptation or jumbled adaptation draws the users attention and then does not allow for additional information from secondary adaptation or the movement of the position marker, based on the users position and the relative position of further feedback.

10/27 = 37% of Clustered users who had an altered experience received a negative experience.

10 / 46 = 22% of overall Clustered users had a negative influence

Distributed

Distributed – Negative transition factors – 1/3 – 4-6			
Entry	Result	Freq.	Factor
User Factors			
2	5	1	(R) Secondary adaptation moves actors left – User moves to left gap – notices marker and new window – User corrects
2	6	2	(N) Secondary adaptation – Marker moves past user – User does not respond – Engages with initial adaptation (R) User confidently approaches left hand end – Does not notice marker or new window
3	6	1	(N) Initial small adaptation – Secondary adaptation – User does not engage with any aspect of adaptation
Display Factors			

2	5	2	(N) Secondary adaptation draws users attention – Marker moves away as user is responding to secondary – User identifies and corrects (R) Secondary adaptation – User moves to new gap – Marker moves right – User identifies marker and new window – User corrects
3	6	3	(N) User responds to initial adaptation – Secondary adaptation - Marker moves past location – user engages with first adaptation

(4/4) – All transitions resulted in negative transitions 1/3 – 4/6 = 4/46 = 9%

User factors – The initial adaptation draws the user to a location where they stop engaging with the display. The user is not in a good location to identify secondary adaptations or the position marker. This can be related to the distributed configuration and an inability for users to further identify changes on the display.

(5/9) – Just over half of the factors caused negative transition 1/3 – 4/6 – 5/46 = 11%

Display factors – User respond to initial adaptation but the position marker is in a location where they are able to identify a necessary change and are led to the new location. The initial adaptation is in a location which does not support further understanding of the display, the user has already identified an adaptation and it is in-keeping with their initial decision making, such that there is no desire / ability for users to change their landing position.

9/23 = 39% of altered experience Distributed users had a negative experience.

9/46 = 20% of total Distributed users had a negative experience.

Positive factors of staggered to smooth engagement

While there were a number of factors which resulted in users having a worse experience due to factors of the system, there were an equal number of users who had a better experience due to some aspect of the system.

Clustered

Clustered – Positive transition factors – 4-6 – 1/3			
Entry	Result	Freq.	Factor
Display Factors			
4	1	3	(R) User enter confidently towards the gap – During entry the user identify the marker and follow it to find the new window
4	3	7	(N) Small adaptation in front of user – User slows and a gap is created – User has the opportunity to identify factors (N) Secondary adaptation moves actors back – Position marker moves to the right user can engage (R) User enter confidently to the right hand gap – Once there users engage with factors of the display

10/27 = 37% of altered Clustered users had a positive experience

10/46 = 22% of all Clustered users had a positive experience

In all there were 10 cases, all in the Clustered configuration and all due to aspects of the system, which caused user to transition from a staggered interaction to a smooth interaction. These were all relative to the confidence of the user upon entry. It appears that the position of the marker relative to the entry allowed for a user to identify their point of interaction while they were entering. There was a secondary aspect of the adaptation which caused users to slow as they were not able to identify the meaning and relationship of the adaptation, in this time the position marker informed the user as to where to interact as a secondary factor to their initial confusion upon entry.

Distributed

In the distributed case there were no examples of users' experiences transitioning from staggered interactions to smooth. Users either encountered an equal or worse experience as a result of user or display factors. All examples of positive influences on user behaviour were seen transitioning through various behaviours within the smooth interaction, i.e. the system worked to improve the understanding of the user while they were already on a smooth interaction. This would indicate that aspects of system function can help users to improve their experience as long as they are able to engage with and understand the factor.

Caveats and interesting behaviours

In several cases in both Clustered and Distributed configurations, there were examples where the user behaviours stayed fundamentally the same, however, there were issues of the system or user behaviour which merited notation. These examples identify several cases where the overarching behaviour model was the same throughout the experience, but an aspect of system or user behaviour required identifying as an individual case.

Clustered

Clustered – Caveat factors			
Entry	Result	Freq.	Factor
Display Factors			
2	2b	5	(N) There is a jumbled adaptation – This draws attention but does not help the user – Marker moves to the right and users follow
2	2f	2	(N) There is a clear adaptation – User arrives in the gap – Window is not shown in the gap – User cannot identify the marker or window

These changes all relate to the interaction of users with factors of adaptation, where initially the adaptation causes confusion to the users and draws there attention, however, while they are observing the display it is possible for interaction with the position marker such that better understanding can be found.

Alternatively, the user responds to the adaptation correctly, but there is a secondary factor which draws the marker away before the user has identified a relationship. This leads to the user failing the task due to engaging with the adaptation.

Distributed

Distributed – Caveat factors			
Entry	Result	Freq.	Factor
Display Factors			
2	2c	3	(R) Small adaptation on right end – Marker moves right – User moves past the marker to the gap – Window is shown – User engages (R) Small adaptation on right end – User moves directly to right end
2	2f	3	(N) User follows adaptation and marker – Window is hidden – user cannot identify the point of interaction (R) Adaptation on left – User aligns to gap – Marker moves to the right – User stays in gap – User does not identify window shown on right (R) User responds to initial adaptation – User identifies marker – Marker moves right - User stays at adaptation

In these cases all users are engaging with the adaptation, however, the initial group are able to pre-empt the position of the new window due to an initial adaptation. The users pass the marker and only engage with it again once they are in the correct location.

Alternatively users follow the initial adaptation but the marker moves away or the window is hidden, the user is not able to identify the any further feedback for interaction as they have already responded and are not able to see or gain understating form their position.

Clustered vs. Distributed

In all of these cases of alternative interactions or caveats, there is no significant difference seen in either configuration or compared to the relevant interactions already documented. These have been identified as caveats, or interesting factors of the interactions, as there was a clear difference in the nature of the interaction, such that users would not achieve the task or would have an alternative interaction than the expected one, however, the underlying reasons for this change are essentially the same as already documented.

Distribution of adjusted experiences					
	(1/3)	1/3 – 4/6	(4/6)	4/6 – 1/3	Total
Clustered					(27/46)
User					4/46 = 9%
Positive	0 = 0%	0 = 0%	0 = 0%	0 = 0%	0 = 0%
Negative		4 = 9%			4/46 = 9%
Display					23/46 = 50%
Positive	1 = 2%			10 = 22%	11/46 = 24%
Negative	7 = 15%	4 = 9%	1 = 2%		12/46 = 26%
Total	8 = 17%	8 = 18%	1 = 2%	10 = 22%	27/46 = 59%

Distributed					(23/46)
User					4/46 = 9%
Positive	0 = 0%	0 = 0%	0 = 0%	0 = 0%	0 = 0%
Negative		4 = 9%			4/46 = 9%
Display					19/46 = 41%
Positive	10 = 22%				10/46 = 22%
Negative	3 = 6%	6 = 13%			9/46 = 20%
Total	13 = 28%	10 = 22%	0 = 0%	0 = 0%	23/46 = 50%

Distribution of Altered and Non-Altered interactions							
	1	2	3	4	5	6	Total
Clustered							
Altered							
Start	2	13	1	11	0	0	(27)
End	4	7	7	1	3	5	27
Not-Altered	8	11	0	0	0	0	19
Final	12	18	7	1	3	5	46
Distributed							
Altered							
Start	1	17	5	0	0	0	(23)
End	5	8	0	1	3	6	23
Not-Altered	9	12	1	1	0	0	23
Final	14	20	1	2	3	6	46

Total count of users in the Behaviour 1					
	Novice-1st	Novice-2nd	Reapeat-1st	Repeat-2nd	Total
Clustered					
Initial	0	0	8	1	9
Altered	0	0	-2	4	4/-2
Final	0	0	6	5	11
Total	0	0	8	5	13

Distributed					
Initial	0	1	5	4	10
Altered	0	4	0	1/-1	5/-1
Final	0	5	5	4	14
Total	0	5	5	5	15

Total altered interactions of user in Behaviour 1					
	Start	Final	Freq.	Influencing Factors	Total
Clustered					
Repeat-1st	1	4	1	User identifies marker – Pre-empts movement – As user gets to location begins to follow marker again	-1
	1	6	1	Jumbled adaptation – User interacts with marker – Marker begins to lead right – User moves left	-1
Repeat-2nd	3	1	1	Upon entry there is a jumbled adaptation – User waits while adaptation is confused – User engages and follows position marker	1
	4	1	3	User enter confidently towards the gap – During entry the user identify the marker and follow it to find the new window	3
Distributed					
Novice-2nd	2	1	4	Initial adaptation draws user to centre of space – Position marker is easy to engage with from user position	4
Repeat-2nd	2	1	1	User follows initial adaptation – Second adaptation - Marker moves towards new gap – User responds to marker and second gap	1
	1	6	1	Adaptation in centre – User identifies marker – Marker moves towards centre – User moves left	-1