# Territoriality and Behaviour

# On and Around

# Large Vertical Publicly-Shared Displays

by

Alec Azad

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I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

# Abstract

Large displays and information kiosks are becoming increasingly common installations in public venues to provide an efficient self-serve means for patrons to access information and/or services. They have evolved over a relatively short period of time from non-digital, non-interactive static displays to more elaborate media-rich digital interactive systems. While the content and purposes of kiosks have changed, they are still largely based on the traditional single-user-driven design paradigm despite the fact that people often venture to these venues in small social groups, i.e., with family and/or friends. This often limits how groups collaborate and forces transactions to be serialized. This thesis explores design constraints for interaction by multiple social groups in parallel on shared large vertical displays.

To better understand design requirements for these systems, this research is separated into two parts: a preliminary observational field study and a follow-up controlled study. Using an observational field study, fundamental patterns of how people use existing public displays are studied: their orientation, positioning, group identification, and behaviour within and between social groups just-before, during, and just-after usage. These results are then used to motivate a controlled experiment where two individuals or two pairs of individuals complete tasks concurrently on a low-fidelity large vertical display. Results from the studies demonstrate that vertical surface territories are similar to those found in horizontal tabletops in function, but their definitions and social conventions are different. In addition, the nature of use-while-standing systems results in more complex and dynamic physical territories around the display. We show that the anthropological notion of personal space must be slightly refined for application to vertical displays.

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# Chapter 1

# Introduction

In shopping malls, amusement parks, airports, and other public spaces, large digital displays are replacing traditional signs as the medium of choice for communicating information to the general public. Historically, non-digital displays could only support one-way communication as they broadcast general information to the public. The recent digital revolution now permits bi-directional communication, unlocking an entirely new collection of tasks that can be afforded, most notably, transactional tasks, creating self-service interactive kiosks. With this transformation, these displays may now range from static digital signs, showing generic, long-lasting information such as a directory or map, to fully-interactive kiosks with dynamic and personalized content. Thus far, large digital displays have mostly been used to strictly serve ambient information to the general public (e.g., flight information at an airport, event schedules at a convention/conference), affording little to no interactivity. On the other hand, interactivity has largely been reserved for small single-user kiosks (e.g., movie ticket kiosks, grocery store checkouts).


**Figure 1.1:** Artist's depiction of user groups engaging a large publicly-shared vertical display in parallel (left). A man interacting with a novel large display installation (right).

This paradigm is particularly dated because people tend to venture out to public venues in social groups, e.g., friends, family, coworkers, colleagues. The problem becomes clear: when a single member of a group interacts, the others can only passively observe, or at best, communicate their ideas verbally. Quite often, tasks can benefit from collaboration, which would not only make productivity gains, but create a more engaging experience for the entire group [32]. Thus, it begs the question if combining these two systems would inherit the advantages of both systems. For example, a map of an amusement park can be augmented with information about promotions or events in the immediate vicinity, and people can customize this information further with explicit interactions. Building on the amusement park map example, multiple family groups could share a single wall-sized display, with each group planning their day by selecting and organizing shared information from a common map (Figure 1.1).

Supporting information sharing and concurrent interaction among multiple independent groups is challenging and presents a problem that requires a very general solution. Such a system would need to support one individual and many individuals; one social group and many groups; or, a mix of both. Distinct parties may wish to collaborate amongst themselves, or subsets may branch off and choose to work independently. Furthermore, users may transition between these states at-will, working collaboratively with their group at first, then independently, or vice versa. Effectively, groups are interacting on the same screen asynchronously, working on different, even loosely-coupled, tasks. Designing a system that can support such flexibility requires some research into how groups behave in similar situations and how territoriality is governed on vertical large-screen displays which manifests itself in two ways: physically in front of the display and virtually on-screen [37].

This thesis explores the idea of public kiosks that support collaboration between social groups in parallel on shared large vertical displays. To this end, this work details accounts of people's behaviour at and near public displays using two user studies to gain a better understanding of what features to support and consider when designing such systems. Based on these detailed observations, this thesis aspires to establish fundamental design specifications for public kiosk systems that will create a more fluid and engaging user experience for everyone outside the home. More specifically, to inform the design of large, public, interactive displays for multiple groups, this thesis presents accounts about how these groups interact with themselves, others, and the display itself.

## 1.1 Open Research Questions

The problem of territoriality and behaviour on and around large vertical publicly-shared displays is not clear and is a research problem with many concerns that need addressing. We break down this broader problem into smaller, more targeted research questions:

1) How do people approach, engage, and conclude their sessions at public kiosks?
   a) How does group size affect each of these stages of interaction?
   b) How do groups position and orient themselves during interaction and how do they morph over time?
2) How does territoriality play into multiple, non-collaborating groups at interactive large-screen vertical displays?
   a) How do people assert their space physically in front of the screen?
   b) How do people partition virtual (on-screen) territories?
3) How do groups collaborate on:
   a) Current pubic kiosks?
   b) Interactive large-screen vertical displays with other groups?
4) What other common behavioural patterns are exhibited by social groups while at public kiosks and interactive large-screen vertical displays?

## 1.2 Contributions

This thesis provides detailed accounts of the territories and behaviours that emerge both on and around displays in collaborative and non-collaborative parallel multi-group usage. Data are collected from both a field and controlled study. The contributions of this thesis, grouped by their respective experiment, provide detailed insights on the following topics.

### 1.2.1 Field Study Contributions

- ***User Role Identification*** – This thesis classifies users into three types of functional roles: driver, active observer, and passive observer. Drivers are those who controlled progression through the task. Active observers provided suggestions or assistance to the driver, either verbally or via hand gestures (e.g., pointing). Passive observers do not contribute to the task; however, may still overlook the display. Observations show that roles are not static and users frequently rotated between different roles.

- ***Effects of Task Complexity*** –Observations on three kiosks of varying complexity provide strong guidance of what to expect from having different levels of complexity in software applications. Specifically, it was seen that longer and more complex tasks led to an increased likelihood of role rotations and wandering behaviour (intermittently leaving and returning).
- ***Limiting Factors for Parallelizing Usage*** – One of the key results from this thesis, from having observed the mall directory specifically, reveals that even given ample space in front of a large display, approaching groups tend to elect to "wait in line", queuing behind preexisting groups at the display. This verifies the similar behaviours Peltonen *et al.* observed with their CityWall research project [31].

### 1.2.2 Control Study Contributions

- ***On-screen Territories*** – This thesis presents evidence that the on-screen vertical display territories are analogous to those found in tabletops ([37]), but manifest with key alterations and draw different perceived social expectations surrounding them. Namely, distinct regions of personal, storage and public territories emerged.
- ***Physical Territories*** – This thesis documents how groups of varying sizes maintain relative positions to one another at the display. This work reveals a very noteworthy difference between how two individuals versus two pairs share space: individual parties had a clear bias for keeping larger distances between themselves, whereas two pairs were seemingly more comfortable being closer together and more freely engaged in casual conversation.
- ***Perceived User Experience*** – At the conclusion of each session, participants were asked to rate their experience collaborating on a shared vertical display medium as well as note any additional comments. Overall, there was a sense of satisfaction with the display and a clear "fun factor" with working collaboratively which motivates this research space further. Although, early signs of fatigue began to show by some after the 30-minute sessions.

### 1.2.3 Contributions from Both Studies

- ***Approach Patterns, Physical Layouts and Orientations*** – In both studies, inter-group and intra-group movements were catalogued and tracked over the duration of engagement. For the observational study, we additionally recorded approach patterns.

This thesis also discusses the implications of these contributions on establishing system requirements for group identification, interaction design, and display organization. It explores how on-screen territory can be allocated to respond to off-screen behaviours and influence them. The data presented can be leveraged by designers of large public interactive displays to entice, support, and influence group actions on and around the display.

## 1.3 Context

As a requisite to understanding the context of this and related work, it is critical to understand that there are three general types of environments to consider for behavioural analysis of the use of large displays by groups of users: private, semi-public, and public environments. Private environments allow maximal privacy, such as in the home. Semi-public spaces are spaces in public that are controlled or have a specific structure, i.e., people within the same space have something in common or are somehow connected with one another, such as a meeting room or a classroom. Public spaces are open, uncontrolled spaces (the “wild”) where people sharing the space may have absolutely no affiliation with one another. As stated, this work is tailored for systems deployed in public spaces such as in an amusement park (see Figure 1.1). Unlike in a private or semi-public environment where total control of a display can be taken at-will by a collaborating group or individual, systems in public spaces should ideally support fair sharing and asynchronous use. Non-technical analogues of this concept exist abundantly: consider a park bench where individuals, couples, or larger social groups can walk up independently of one another and “claim” a portion of the resource, then vacate at-will.

It is important to note that people behave differently in different environments depending on several factors including social, cultural, and religious influences. For example, in regions under strict Islamic rule, men and women out of wedlock are forbidden to come in intimate contact in public. Such and similar limitations are important to keep in mind. The reader should note that this research, along with all related research, was conducted in Western culture, unless otherwise noted.

## 1.4 Organizational Overview

The remainder of this thesis begins with a comprehensive literature review of research in the related areas: Territoriality and Behaviour, Large-screen and Public Display Technologies, and Public Kiosks. We first explore works in territoriality from both a more primitive anthropological and psychological perspective, to more modern works adapted in Computer-Supported Cooperative Work

(CSCW). Insights from past CSCW-related work on both vertical and horizontal surfaces (i.e., tabletops) help sculpt our overall understanding of social behaviours, particularly around this genre of technologies. We also investigate past projects surrounding large-screen and public displays to enrich our understanding of how previous authors have applied concepts of territoriality to their designs, and the positive and negative implications that followed. Tangentially, benefits of using large-screen displays, in and of themselves, are outlined in order to motivate the broader problem as well as to provide leads on what sorts of tasks and/or UIs stand to benefit most from large screens. Similarly, research on public kiosks is briefly visited.

The following chapter, Chapter 3, presents an observational field study accompanied with an in-depth analysis of the recorded results. We visited three different publicly-located kiosks and displays to survey how people currently use existing technologies: a non-digital mall directory, cinema ticket kiosks, and photo-developing kiosks. These settings serve as justifiably-good substitutes to our envisioned system portrayed in Figure 1.1 which is not yet even remotely wide-spread. People's familiarity with these installations remove many experimental confounds, such as learning-curves and the novelty effect[1]. After dozens of recorded behavioural patterns, certain generalities are drawn that can be used to infer design, particularly with regards to territoriality in front of a given system. Limitations of existing deployments are identified such as an apparent "queuing" of groups in front of a display: serialization of usage, rather than a more efficient parallelization.

The field study informs the design and subsequent analysis of a control study discussed in Chapter 4. The purpose of this second experiment is to dig deeper into notable patterns seen in the preliminary field study as well as to further eliminate confound variables, which is a particular concern for "in-the-wild" studies. Furthermore, this second experiment focuses less on territoriality in front of the display and more on the on-screen territories as well as group dynamics that emerge and how they change over the duration of interaction. To simulate a generic (computation) task, participants were asked to solve jigsaw puzzles on a large vertical whiteboard. Group size and puzzle configurations were two primary control variables. It is shown that participants allocate regions of screen real-estate to serve different purposes similar to those on tabletops [37], but with notable

[1] The novelty effect occurs when initial reactions to a new technology are seemingly positive, however, not because of its practically, but rather of its novelty. Interest quickly degrades over time.

differences. In addition, observations reveal the social etiquette behind how people intrude these regions as well as each other's proximities.

With the analyzed results of these two studies, design implications are established in Chapter 5. These are inferred from three perspectives core to this research: 1) how social groups interact with each other and amongst themselves, 2) the management of concurrent on-screen workspaces, and 3) group and role identification. The goal of the design specifications is to create a more engaging experience for all members of social groups by enabling concurrent collaboration, and to maximize efficiency by promoting sharing by multiple groups simultaneously, regardless of individual tasks. Thus, these specifications should be consulted when realizing a large-screen publicly-shared interactive kiosk.

The thesis is concluded in Chapter 6 with a summary of the key findings from both experiments. We encourage further studies into this area by having a brief discussion on future research in this space.

# Chapter 2
# Background and Related Work

In this chapter, we present a comprehensive overview of research related to territoriality and behaviour on and around large vertical publicly-shared displays. The novelty of this work results from studying territoriality and behaviour on technologies characterized by having this under-explored cross-disciplined nature of combining large, with vertical, with public, and with shared displays, and thus, research involving this particular intersection is scarce. For this reason, work involving as many commonalities is reviewed in an à-la-carte fashion. With that said, there are three core areas of research related to this work: *territoriality and behaviour*, *large-screen and public display technologies*, and *public kiosks*. Motivation for this work will then be provided.

## 2.1 Territoriality and Behaviour

Territoriality must address the psychological and sociological behaviours portrayed by users if a natural fluid interaction is to take place on public large-screen surfaces. A first step to better understanding users, especially in public spaces, is the role human psychology plays with regards to territoriality. We first consider natural settings from an anthropological perspective (i.e., without the potential influences of a technical system). Then, more modern studies will provide insight on how territoriality is affected, if at all, with the introduction of shared technologies.

### 2.1.1 Technology-Independent

Behavioural and neuropsychological studies suggest that the brain constructs three basic zones of space: the personal, peripersonal and extrapersonal [17]. *Personal space* refers to the space occupied by our bodies [2, 7, 41]. *Peripersonal space* is defined as the space immediately surrounding our bodies, which can be reached with our limbs [3, 27]. Space beyond this scope is considered *extrapersonal space* [3, 33]. Human lesion studies and monkey neurophysiological studies provide evidence for this functional segregation of these spatial representations. Some researchers in this field further breakdown the space around us. In widely-accepted anthropological research by Hall, four proxemic zones have been identified: intimate (less than 1.5 feet), personal (1.5 – 4 feet), social (4 – 12 feet), and public (12 – 25 feet) [13]. It is this breakdown that is often adopted in proxemics (e.g., [1, 13, 42]). These explicit zones will serve as references/baselines to our study on territoriality.

Danninger *et al.* [10] studied using social geometry of co-workers in semi-public office environments to help infer opportunities for devices to interrupt users to minimize disruptions in a ubiquitous workplace environment. Using heuristics built on Hall's definitions, they developed a social-geometry engine that gauges the engagement of participants in group meetings based on the relative positions and orientations of their bodies. The engine used computer vision to convert the positional layout of participants into a directed, weighted Boolean graph where nodes represented individuals and directed-edge weights were dynamically adjusted in proportion to the amount of time the head was facing that direction (Figure 2.1 shows the sample graph included in their paper). They also applied their engine in the design of an office cubicle that automatically mediates communications between co-workers by automatically rendering the separating wall as transparent (from opaque) when the system recognizes intent to communicate based on joint orientation. There was no observational component in the study to suggest why they chose the heuristics that they did; instead, they were built adopting Hall's definition. Admittedly, the work lacked rigorous evaluation, but initial experiences were quoted as "promising" and partly serve as motivation for this work. One of the objectives of this thesis is informing Group and Role Identification (discussed in 0): automatically segregating social groups collected in front of a shared vertical surface for personalized interaction. Danninger *et al.*'s engine was not used explicitly in this thesis; rather, it complements this objective. That is, given its preliminary success, their system can be used to supplement the findings of this research as they are well-connected.

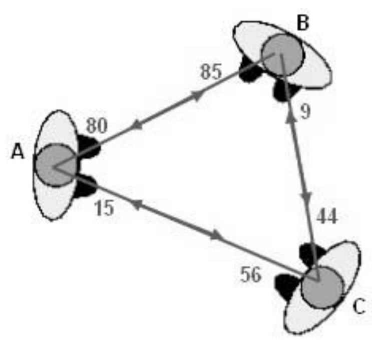


**Figure 2.1:** Graph with statistically weighted edges for attention.

### 2.1.2 Technology-Dependent

Studies on behaviour and territoriality on and around large vertical displays exist but are limited, and so we look beyond to the results from tabletop research to provide a baseline. Regardless of horizontal or vertical orientations of a surface, collaborating groups must ultimately appropriate surface real-estate and command objects to accomplish activities. This commonality is good justification for why tabletop research serves as a reliable source for our work. Obviously, by nature of the alternate surface orientation there will be differences that emerge and the results from this thesis will determine what notions are transferable and what is not, as well introducing new concepts.

#### 2.1.2.1 Private and Semi-public Environments

Work by Scott *et al.* [37] is arguably the most similar to the work covered in this thesis. They investigated concepts of territoriality and behaviour in private and semi-public settings; however, around single-display groupware using tabletop surfaces. Most notably, they observed three distinct functional zones on a shared tabletop surface, namely, tabletop territories: *personal*, *group*, and *storage territories*. These territories emerged in both formal and casual scenarios. Similar findings were observed by Kruger *et al.* [26] in their work looking primarily at the role "orientation of objects" plays on tabletop surfaces. It will be shown that analogues to these territories can be drawn to vertical displays in this thesis and so are described in detail below.

##### 2.1.2.1.1 Personal Territory

Personal territories allow people to reserve a particular area of the table, as well as task resources, for personal use. Its purpose is to facilitate a person's actions related to the group activity, but also allows people to disengage from the group activity. It can be considered as a "safe" place to experiment with ideas before broadcasting them to the group. With respect to the group collaboration, personal territories are often monitored by others and constructive criticism may occur, or, if a tool if needed, the owner of the tool can be easily identified by inspecting this territory.

Personal territories are most often located directly in front of people, but most certainly at least within close proximity. This was also confirmed by Tang [40] in his observational study on group collaboration. We can relate Scott *et al.*'s findings here back to works by [3, 27] and deduce that personal territories exist in peripersonal space (see 2.1.1). Thus, where personal territories are set up depends entirely on seating position. The size and shape of this territory are influenced by several factors:

- *Number of collaborators and seating arrangement* – If seated alone, a person will claim the entire table as personal territory. As more and more people join, territories shrink to evenly distribute surface real-estate.
- *Size of the table* – Simply dictates how much real-estate is available to partition.
- *Task activity* – Personal territories contract and expand based on whether people are currently working independently or collaboratively.
- *Task materials* – Different resources, such as letter-size papers to small Post-it notes, require different amounts of space to allow for easy manipulation of objects.
- *Visible barriers* – Creases or marks in the surface may interfere with how people appropriate space.  For example, food court tables often have a line marked down the middle which takes care of space allocation to alleviate social awkwardness.

##### 2.1.2.1.2 Group Territory

The group territory is the communal space shared by collaborators to perform the main task's activities. From [37]'s study, it typically covers any tabletop space that is not occupied by personal territories (see 2.1.2.1.1). Consequently, the factors that affect the size and shape of personal territories, in turn affect group territories. Group territory is used as a medium to transfer task resources, either by handing off items via the workspace or by depositing items on the workspace to be picked up later when needed. For *tightly-coupled activities* (e.g., assembling a puzzle, creating a product design), the group space is more universally shared than *loosely-coupled activities* (e.g., assembling a room layout). When activities are more loosely-coupled, collaborators tend to partition the group workspace implicitly. In this case, participants in [37]'s study seemed less protective the further the partitions were apart.

Orientation is a common feature looked at by tabletop researchers since participants are seated around the table. For tightly-coupled activities, collaborators tend to adopt "group orientation", orienting items with the main task. In contrast, in a drawing task, Tang [40] reported people drew pictures oriented towards different subsets of the group trying to gain attention. This suggests that orientation on tabletop surfaces is strongly task-specific. The advantage of vertical displays is that this facet is less relevant since everyone shares the same orientation and so is not addressed in this thesis. It is, however, worth noting this advantage vertical displays have over their horizontal counterpart.

##### 2.1.2.1.3 Storage Territories

Storage territories serve as holding areas for task resources (e.g., tools, references) and non-task resources (e.g., food and drinks) and sit on top of either personal or group territories. They can initially be located anywhere on the table, but have mobility and may float around over the duration of interaction; however, they tend to migrate towards the edges as interaction progresses. According to [37]'s observations, items in storage seemingly carry little organizational structure and were typically oriented towards the owner. In the same study, piles of physical items in storage were routinely laid out and expanded as people search through their contents, then re-tidied and collapsed when the desired item was withdrawn.

##### 2.1.2.1.4 Discussion

The results summarized above are conclusions based on studies involving a single collaborating group. That is, in all the observed activities, all the participants were working together towards a common goal, thereby simplifying the general problem. The question that still remains is how behaviour and territoriality are exhibited in more general walk-up-and-use displays where multiple social groups are independently collaborating on separate tasks. To clarify with an example, imagine a family planning their day on an interactive itinerary while simultaneously sharing the display with another couple browsing for nearby places to eat breakfast. It is yet unclear how these [37]'s principles would transfer, if at all, to this more general problem space.

#### 2.1.2.2 Public Environments

The shortcoming of the works described in the previous section (refer to 2.1.2.1) is that the experiments were performed in strictly non-public spaces. Collaborating participants in semi-public studies have, by definition, some degree of pre-established relationships (e.g., colleagues) and this changes the social dynamics as any social "awkwardness" is alleviated. Not to mention, everyone is working collaboratively towards a shared goal. Naturally, we turn now to works which focus on systems deployed in public spaces: the "wild". The findings of semi-public studies are still applicable, as will be seen, but we must extend our knowledge further and consider public environments. Fortunately, research exists that look at behaviours around shared surfaces deployed in public environments – both vertical *and* horizontal. Strictly speaking, while work on publicly-located horizontal surfaces is less relevant, some of the observations provide generalizable insights on social behaviours, such as teamwork, conflict management, and turn-taking protocols.

#### 2.1.2.2.1 Shared Vertical Displays

Shared vertical displays in public are most applicable to this thesis; however, it is relatively under-explored in research and even more under-used in practice. One possible reason for the limited deployment of interactive large displays may be user reluctance to engage with these devices in public venues. Brignull *et al.* [4] considered the early stages of interaction with public large-screen displays. They identified root causes of both users' reluctance (e.g., fear of embarrassment) and attraction (e.g., "honey pot" effect[2]) to use large-screen displays in public areas. Hornecker *et al.* [18] also noted the strength of the "honey pot" effect in their work.

One exception to the lack of public deployments of interactive shared vertical displays is CityWall [32], a 2.5 m wide public multi-touch display deployed outdoors in an urban environment that enables people at large public events to upload and share photos. This study, however, focuses on user perception and attitude towards the technology rather than territoriality. The researchers studied collaborative behaviours, and found CityWall provided a sense of *"active spectatorship"* as participants felt much more engaged in the event(s) knowing they could be photo-content submitters (via a smart phone). Several reinforcing quotes were given that suggest that people are very accepting of such technologies. Some notable quotes being:

> *"I can't see that one would go there alone to look [at pictures], unless you know that there is a specific photo or something. It works better with a group. It's also more fun maybe that way, as many people can see what [pictures] have been taken."*
>
> [On privacy] *"It doesn't matter. It isn't so public that it would matter that you have a photo of yourself there. But if it were a bigger screen, then it could be a little more uncomfortable. Of course depending on the fact whether one wants her own picture to be there or not. But it did not matter as it was fun to test how it works."*

The second quote clearly demonstrates a user's concern over privacy and comfort level as screen size increases. Observations and quotes were recorded from a combination of one, four-day event and one, two-day event (effectively six days) using 13 randomly-selected spectators and so, unfortunately, it is

[2] The "honey pot" effect refers to the attraction to a device, or more generally any object, caused when others are already showing interest by interacting with it.

difficult to say if this technology suffers from the notorious novelty effect. Furthermore, the task, while highly-parallel, was not particularly collaborative. Although multiple groups were able to engage the display simultaneously, each user explored different photos individually. In the end, the results are less focused on issues regarding territoriality, but it does give firm insight and motivation for work in this space with the knowledge that people are more accepting of, rather than intimidated by, large display technologies.

In a follow-up study, Peltonen *et al.* [31] examined the social interactions that occurred while users interacted with the same CityWall display. Manual reviews of recorded video revealed a total of 1199 people in 512 groups interacted with the display over an eight-day observation period providing much more statistically sound findings as compared to their earlier study conducted a year prior ([32]). Many social dynamics are expressed as a function of group size, thus it is very important to document as will be seen in this thesis. For reference, the distribution of group sizes for [31]'s study was: 18% individuals, 72% pairs, ~10% groups of three, and very rarely groups of four. The duration of engagement is broken into three chronologically-ordered segments: *approach*, *interacting with others*, and *concluding actions*; however, only the first two are relevant and therefore discussed. It is critical to this study to understand these particular observations since much of the behaviour was seen repeated in our preliminary observational study (Chapter 3).

I. Approach

The system was in use only 8.8% of its uptime, but recognizing that 19% of the sessions began when at least one other group was already at the display reinforced the notion of the "honey pot" effect for such systems. The authors quoted that the outdoor system's visibility was not ideal: camouflaged by being surrounded with so much visual clutter in an urban environment. User comments confirmed this, emphasizing that the display was hard to notice without anyone else using it. This simple observation should be taken under advisement when deploying systems in public spaces.

II. Interaction with Others

Their work presented several social concepts around shared large displays including, social learning (teamwork), conflict management, and turn-taking protocols. With regards to user experience, all users interviewed admitted that the installation was most fun to use together with acquaintances: further motivation to deploy such systems. Being in a casual setting,

> people's hands were sometimes preoccupied holding items such as soda cans or shopping bags. In some of these cases, teamwork was leveraged to manipulate objects on-screen that required two-handed techniques (e.g., image scaling). A valuable lesson from this is to refrain from using two-handed interaction techniques for walk-up-and-use systems. A key outcome of the study showed that even with a width of 2.5 m, groups would sometimes queue up behind an interacting group even when plenty of space was available. This suggests that an appropriate moment of entry is not simply a matter of available space. This thesis further emphasizes this pitfall and discusses possible solutions to this problem.
>
> Conflict management is a concern for all shared systems. Observations showed that when one group manipulated content on-screen that interfered with that of another group, the offended group's response is unpredictable: either stepping back or making eye contact with acquaintances, rather than with the offending group. These events may be perceived both positively (triggering laughter) or negatively (causing frustration).

Most observations reported were specific to the photo-manipulation task installed on CityWall. Unfortunately, this task is not very encouraging of collaboration and individuals in the same social groups tended to break apart to explore functionality independently. Research involving more "team-building"-like exercises in parallel should be explored: the niche of this thesis.

Using a revised version of CityWall, named Worlds of Information, Jacucci *et al.* [21] developed a customized user interface for exploring and manipulating photos using 3-D spherical widgets. Most of the work focused on the evaluation of their design; however, they do extend the concept of social learning which can be considered in a general sense. Specifically, they formally enumerated all the observed behaviours as users assisted each other. From observations over a three-day period (number of participants was not recorded) they coded four methods of learning: *individual exploration*, *cooperative exploration*, *passive observation then attempt*, and *imitation*. The first three are trivially defined, and imitation is defined when users go directly to the wall and imitate others. Most users would use some combination of two or more of these methods. In highly-collaborative environments, it is useful to understand how users learn and seek assistance in times of uncertainty so that systems can be explicitly designed to best support them.

2.1.2.2.2 Shared Horizontal Displays

Marshall *et al.* [29] observed all the stages of interaction with a tabletop in an uncontrolled public deployment in a lengthy 32-day study. Their key finding with respect to how people approach tabletops "in-the-wild" was that cohesive groups often did not approach the display together; instead, one member would be attracted to it and wave the rest of his/her group over thereby causing the members to arrive asynchronously. To further complicate the matter, since the system was deployed in a large tourist center, social groups were often fragmented well before interaction and regrouping could occur at the display. Another interesting observation regarding approach patterns was that as individuals walked by the display, noticing the display may cause them to pause and then tap the surface initiating interaction while their body was still oriented in the original trajectory they were walking, i.e., not at the display. This position may hold for several seconds as they are interacting and is evidence that body orientation alone is not a reliable measure of gauging attention. This "in-the-wild" study gave valuable insight in a publicly-deployed tabletop system; however, it is not clear if these behavioural patterns are shared with vertical surfaces.

## 2.2 Large-screen and Public Display Technologies

A majority of the research on large-screen displays has focused on the benefits of a larger display surface and individual/group interaction *on* the display. In their overview of large-screen research, Czerwinski *et al.* [9] summarize cognitive benefits, noting that larger displays improve information recognition and peripheral awareness making them well-suited to navigation tasks. Other researchers have noted productivity gains [8] and improved collaborative interactions [36] around large screens.

While researchers have demonstrated the cognitive benefits of large screen displays, deployments of interactive displays in open public environments are rare [9, 32, 36], as stated before. Many large-screen systems (e.g., Plasma Posters [5], LiveBoard [12], Flatland [30], BlueBoard [36]) have been deployed, instead, in semi-public environments where they are accessible to small co-located groups and not the general passer-by (e.g., in the workplace). While semi-public environments often have multi-person spaces, the role of large displays in these environments is different than their role in open, public spaces. For example, in workplaces the act of taking control of an entire display and customizing it for one's own or a group's use is acceptable, assuming that display co-opting is done to support work [36]. In public, any personalization of a display must still be mindful of other users' need to access generic content. It is not clear that group behaviours in semi-public spaces like the workplace are similar to behaviours in public spaces such as malls, airports, or amusement parks [4].

There exists several works that have explored alternative interaction techniques on large vertical displays. The large physical size presents additional challenges for manipulating content on-screen. For example, objects can exist in extrapersonal space (refer to 2.1.1) – outside of one's reach. This opens a new set of research questions asking how best to address this problem considering time and energy resources. Jota *et al.* [23] presented a comparative study of the performance of three common interaction techniques: grab, point, and mouse. A *grab* technique is a metaphor for how we reach for physical objects, like books on a library. To move an object on-screen, a user would literally walk to it (if out of reach), grab it then drag it to its desired final destination and release. The *point* metaphor uses standard pointing: users point at an object to select it then point to the final destination to relocate. This solution saves the user from having to physically walk to out-of-reach objects. Finally, the *mouse* technique works just like the mouse, but on a vertical pane. Using a task that required sorting several shapes on-screen in a particular order, it was seen that *point* offered the lowest puzzle completion times of the three, then mouse, then grab. While not directly related to issues surrounding territoriality, this goes to show the additional challenges for interface designers of such systems. The study was designed and evaluated for single-user usage, so there was no consideration for others interfering or assisting.

There has been limited work in interaction techniques for large *shared* displays, i.e., multiple users in parallel. A particular research project by Shoemaker *et al.* [38] looked into the intersection of interaction techniques on large vertical (wall) displays and studies on territoriality. Their novel (5 m x 3 m) wall display embodied *body-centric interaction,* where the system recognized, as input, gestures from either arm (with the help of two Nintendo Wii remotes) to interact with menu options contained within a projected whole-body interface (Figure 2.2). Most notably, however, they extended the design to consider territoriality and human cognitive mechanisms that support sensorimotor operations in different coordinate spaces as described by [17] (refer to 2.1.1). They supported sharing and collaboration in these territories by enabling a user to grab a personal datum and 1) drag it to public space so anyone can interact with it, or 2) physically pass it to another user via making close contact with hands. Using theory of personal space, a computing system used the distance between users to draw conclusions regarding coordination, including whether they are directly collaborating. For example, to transfer sensitive or private data, e.g., a PDF file, from one user to another, the

**Figure 2.2:** A user reaches her right hand towards her right hip to access a tool.

**Figure 2.3:** Private data shared by the literal action of passing it to the other user's hand.

metaphor of explicitly "handing off" the information was recognized by the system (Figure 2.3). They did caution that user-user association cannot rely just on proximity alone. Considering eye contact, body lean, or smiling can be leveraged for communicating trust. Evaluation of the system was based on user feedback and was positive. Users had little trouble learning the system and admired its intuitiveness and expressiveness. The deployment was in a semi-public setting and unfortunately, no evaluation with multiple groups working concurrently was performed although they mentioned support for it. Furthermore, the application of a map browser was not particularly a collaborative-centric task.

Research examining people's movement *around* a display has mainly focused on using position to enhance interaction [1, 24, 42]. Both Vogel and Balakrishnan [42] and Ju *et al.* [24] focus on adapting display behaviour based on participants' range from the display. For example, Vogel and Balakrishnan based interaction on an individual's proximity and orientation to the display: *ambient* for more distant passersby, *implicit* for peripheral awareness of passers-by, *subtle* for passers-by who focus on the display, and *personal* for passers-by who approach and interact with the display [42] (shown in Figure 2.4). In Ju *et al*.'s [24] whiteboard system, Range, ink clustering is performed in real time, but the results of computation are displayed to the user only when she steps back from the intimate zone to the personal zone during interaction. In this way, the system does not interrupt the user with recognition results during the writing task. More recently, Greenberg *et al.* [13] demonstrated how proxemics can be used as a mechanism for managing input and information display for surfaces. Ballendat *et al.* [1] introduced the term *proxemic interactions* to describe how an awareness of position, movement and orientation can be used to control interactions in multi-device environments.

Research like these push the frontiers on intelligent user interface design by making systems more “aware” of their surroundings. While researchers have shown the advantages of using proxemics to enhance interaction, they do not describe how people move *around* existing public displays, e.g., their orientation, positioning, group identification, and behaviour within and between social groups: a goal of this thesis. As they stand, many of the design decisions for these projects were chosen heuristically for novelty purposes and do not rigorously consult any prior observational studies on how exactly these zones would be best defined, if at all. This thesis aims to fill this gap so future intelligent UIs can leverage and take advantage of documented territoriality and behaviour.

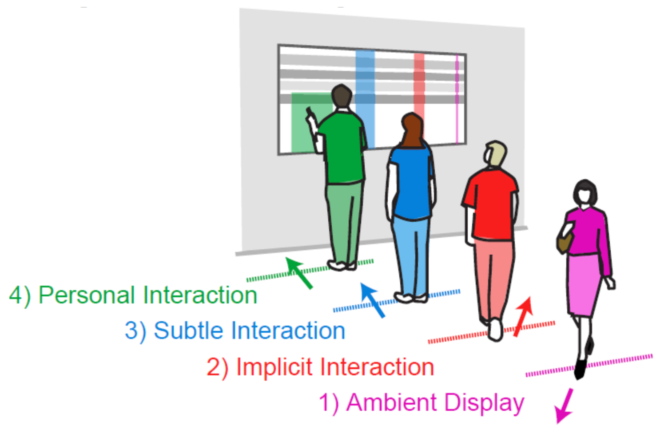


**Figure 2.4:** Four interactive phases, facilitating transitions from implicit to explicit, public to personal, interaction.

## 2.3 Public Kiosks

In comparison to large-screen display research, relatively little research has been done on public kiosk systems. Maguire [28] established a verbose set of heuristics and design guidelines for building public information kiosks. The guidelines describe user requirements, placement constraints, interface design, and privacy issues. The digital Smart Kiosk project [6] implemented a public kiosk which used computer vision to track the movement of passers-by. An animated face on a portion of the display would rotate to orient itself towards people in close proximity which gave the system a degree of awareness. Hagen *et al.* [14] investigated smart interfaces on kiosks. They experimented with dynamically placing content on screen and changing text size based on the user’s height and distance from the screen (Figure 2.5).

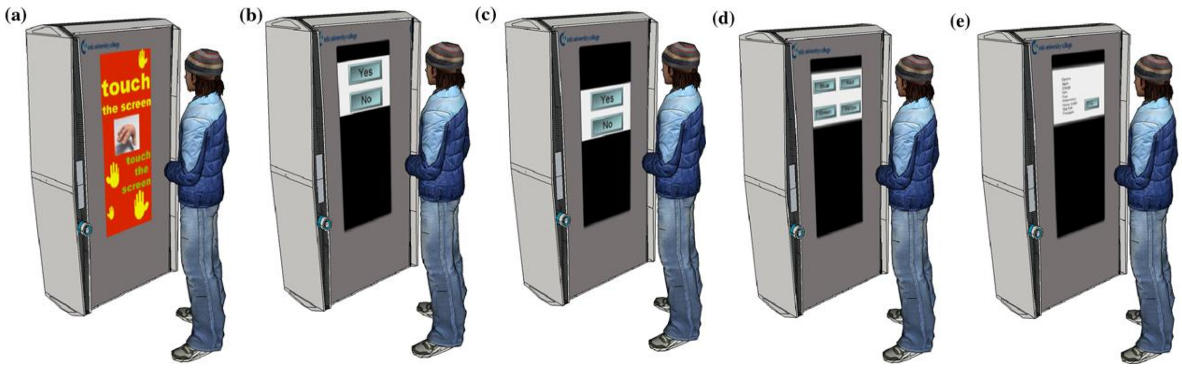


**Figure 2.5:** Dynamically altering the text size and center of interaction on a kiosk.

Interestingly, our informal observations of public kiosk systems in many environments illustrated a contradiction between research and design of these systems and use of these systems. While kiosks were primarily designed around the single-user experience, our observations indicated that groups of users would cluster around these single-user displays. However, surveying related work in public kiosks, we saw no research on the phenomenon of group use of single-user kiosks.

## 2.4 Discussion

An extensive literature review of the subject space shows that there exists an ample amount of research in areas that address certain subsets of “public”, “large”, “shared”, and “vertical” displays. However, the collection of all these characteristics is vastly under-explored. Considering the motivation presented in the Introduction as well as from related work ([32]), these systems can provide a much more engaging and productive experience for people and so, deserves coverage.

Motivated by the research presented in this section, this thesis examines behaviour during the complete engagement of interacting with a publicly-shared display. This includes how users move around a display, how they establish territoriality, and how behaviour changes throughout the engagement. We break the problem into two parts. First, we present an observational field study focused on how people move around existing public displays. This is followed by a controlled study to examine how people manage on-display territoriality and move in the space immediately in front of the display.

# Chapter 3
# Observational Field Study

The goal of this preliminary study is to explore intra-group and inter-group behaviours around displays located in open, public environments. Fortunately, displays exist in these environments. Some are passive repositories of information (for example, the classic shopping mall directory). Others allow interaction for specific tasks (grocery store check-outs, movie theatre kiosks, photo kiosks, etc.). The question then becomes how group behaviour around these existing artifacts can influence the display of information, the allocation of territory, and the design of interactive widgets. More specifically, we are interested in how people move *around* existing public displays: their orientation, positioning, group identification, and behaviour within and between social groups just-before, during, and just-after usage.

In order to most appropriately design a controlled experiment, or determine if one is required in the first place, we begin with a preliminary observational study of how people are currently using existing public kiosk and large-screen systems. In addition to its simplicity, this brings three very important benefits to our research findings: a) participants are unaware of the study, thus their actions are not influenced with the knowledge that they are being recorded, b) this presents a true "in-the-wild" study with a system deployed in its "natural" environment, and c) by choosing universally-available kiosks, people will (most likely) have had prior experience using them eliminating any learning curve or novelty effects. With that said, it is equally important to bear in mind the limitations of such a study. Firstly, the envisioned system (Figure 1.1) does not yet exist as common installations, and so we must settle for those of similar resemblance. Secondly, there is no control over the tasks that are performed on these systems. Regardless of these limitations, the observations from this study will still shed some light onto the notion of territoriality and behaviour on and around public kiosks.

## 3.1 Method

Rather than build and deploy our own public display (e.g., [31] and [32]), we study behaviour around existing public devices: public kiosks and information displays. We chose these devices out of necessity since large interactive displays are rarely deployed, and when they are it is more often for novelty, rather than utility. We argue that the standard kiosks and non-interactive information displays we study have a high level of usefulness and familiarity which increases ecological validity. Moreover, the task performed on these two classes of devices corresponds very well to the multiple interaction phases of future large public displays [13, 42]. Thus, we observed people in three public device settings (pictured in Figure 3.1).


**Figure 3.1:** The three systems used for our observational study: a) cinema ticket kiosk (top-left); b) mall directory (top-right); and c) photo-developing kiosk (bottom).

### 3.1.1 Setting 1: Mall Directory

Mall directories are large signs which guide shoppers to stores and services. In our setting, the directory is a ~100” backlit static display with the bottom half listing stores and the top half colour-coded floor plans for each level indicating the locations of these stores and resources such as elevators, washrooms, and exits. To facilitate searching the map, a standard cartographic grid system is used. This kiosk services brief (< 1 min) information retrieval and navigation tasks and its large size affords parallel, shared usage amongst multiple groups.

### 3.1.2 Setting 2: Cinema Ticket Kiosks

At most large theatres, patrons may purchase tickets using a kiosk. In the setting we observed, there are 4 kiosks, each with a 15” touch display. The area in front of the kiosks is separated with rope barriers, forming four 1 meter wide lines. Interactions with these kiosks are short in duration (1 – 5 minutes) and due to the theatre context, they can be surprisingly social.

### 3.1.3 Setting 3: Photo-Developing Kiosks

These enable customers to select, edit, and print photos stored on personal media. In the setting we observed, there were 4 kiosks, each with a 15” touch display and positioned immediately adjacent to one another. Interactions with these kiosks are generally much longer in duration (< 1 hour), but due to the potential task complexity and social experience, multiple people often collaborate.

## 3.2 Data Collection

Each of the three settings was visited twice. At each visit, we observed people using the kiosks or displays for a two-hour observation period, resulting in 12 hours of observations. Written observations were manually noted, coupled with hand-drawn figures depicting the sequential motions, positions, and orientations of people. For reference, an example of each setting is included in Appendix A. The following features were coded in all cases: *approach pattern*, *layout* (with changes tracked over time), *functional roles* (with changes tracked over time), *interaction techniques*, *nearby-traffic conditions*, *departure pattern*, and *duration of session*. In addition to those core features, others were noted on a case-by-case basis. For example, in some cases, subsets of a group would intermittently break from and return to their group during a session. In this case, the length of the departure along with its influence on the position and orientation of the remaining group members was recorded.

Since we are interested in concurrent usage, we only recorded observations when two or more people used the display concurrently. We identified and tracked groups of people so we could code *intra-group* behaviour (movements within a group) and *inter-group* behaviour (movements between groups and the environment). Note that inter-group behaviours included individuals as a special "group of one" when a group of two or more was also present. In practice, this only occurred with the mall directory.

## 3.3 Results

For brevity, we refer to the three settings as CINEMA, PHOTO, and MALL. In total, we observed 26 interactions involving 59 participants (29 female) for CINEMA, 9 interactions involving 21 participants (13 female) for PHOTO, and 12 interactions involving 34 participants (19 female) for MALL. Table 3.1 provides a summary of the groups we observed. Interestingly, groups of four were rarely seen at CINEMA and never at all seen at PHOTO and MALL. This exact behaviour (or lack thereof) was previously seen with Peltonen *et al.*'s CityWall [31] installation which boasted 2.5 m of width, nearly three times the width of the largest of the three observed venues, i.e., MALL.

| | CINEMA | PHOTO | MALL |
|---|---|---|---|
| **Individuals** | 0 | 0 | 6 |
| **Groups of 2** | 21 | 6 | 8 |
| **Groups of 3** | 3 | 3 | 4 |
| **Groups of 4** | 2 | 0 | 0 |

**Table 3.1:** Observed groups broken down by setting and size.

The three settings provided a good sampling of interaction complexity and duration: typically less than 1 minute for MALL, between 1 – 5 minutes for CINEMA and between 5 and 55 minutes for PHOTO.

### 3.3.1 Intra-Group Behaviours

We segment intra-group behaviours into two stages of usage: *approach* and *interaction*, to study group formations, movement, and general behaviour around the devices.

#### 3.3.1.1 Approach Stage Behaviours

The approach stage spans the period of time beginning when one or more members move towards the device until the group arrives at the device. The primary characteristics in this stage are the group formations as they *move* towards the device and as they *assemble* around the device.

We found three primary types of moving formations: *led*, *asynchronous delayed,* and *simultaneous*. The most common approach was where one or two group members would take the initial step and lead the group to the display with other group members following in different formations (Figure 3.2b, c, and d). In a simultaneous approach, the group walked to the kiosk as an ensemble, maintaining a near shoulder-to-shoulder arrangement (Figure 3.2a). In these two types of approaches, the entire group behaves synchronously, arriving at essentially the same time. A variation of this is the asynchronous delayed approach exclusive to the PHOTO setting. Here one subset of the group approached the device first and initiated interaction, and were joined one to 10 minutes later by the remainder of the group. When a delayed subset contained two or more people, the approach arrangement followed those of simultaneous and led approaches. Not all moving formations were observed in all settings. For MALL, groups were more likely to approach simultaneously rather than led. However, in the CINEMA and PHOTO settings, the led and delayed approach types were more common. In the case of CINEMA, the space between rope barriers made simultaneous three person approaches difficult.

The different formations as groups assembled themselves around the device are depicted in Figure 3.3. These formations were often dependent on the moving formation. For example, with a led approach, if the lead was less than three steps, the leader would take a position which created space for the remainder of the group. If the lead was larger, the leader would position themselves as an individual, and then re-arrange the formation — a formation *morph* — when their companions reached the display. The delayed approach sometimes also triggered morphs between assembly formations. For example, with groups of two, the late arriving member would sometimes be accommodated by the initiator moving over (Figure 3.3n) or be forced to peer over the initiator's (typically right) shoulder (Figure 3.3e, k).

Crowded environments more often resulted in Figure 3.3k. With groups of three, if there were two latecomers, the group always shuffled to accommodate them, but a single latecomer was not accommodated and forced to peer over the initiator's shoulders (Figure 3.3f, m). In the PHOTO setting, engaged members were *not* distracted when a latecomer arrived, and latecomers were more likely to become wanderers.

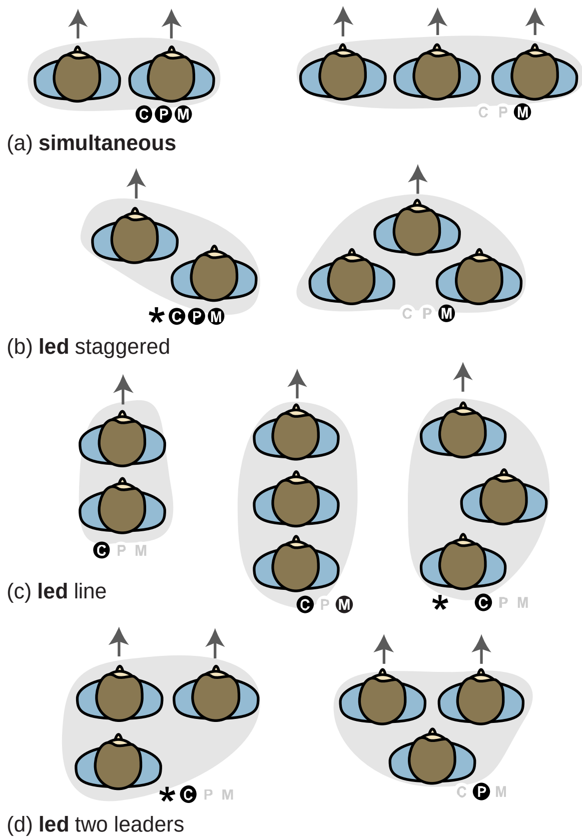


**Figure 3.2:** Moving formations: (a) simultaneous; (b) led staggered; (c) led line; (d) led two leaders. 'C', 'P', or 'M' in black circle denotes an observation for CINEMA, PHOTO, and MALL respectively. '*' denotes mirror version is also valid.

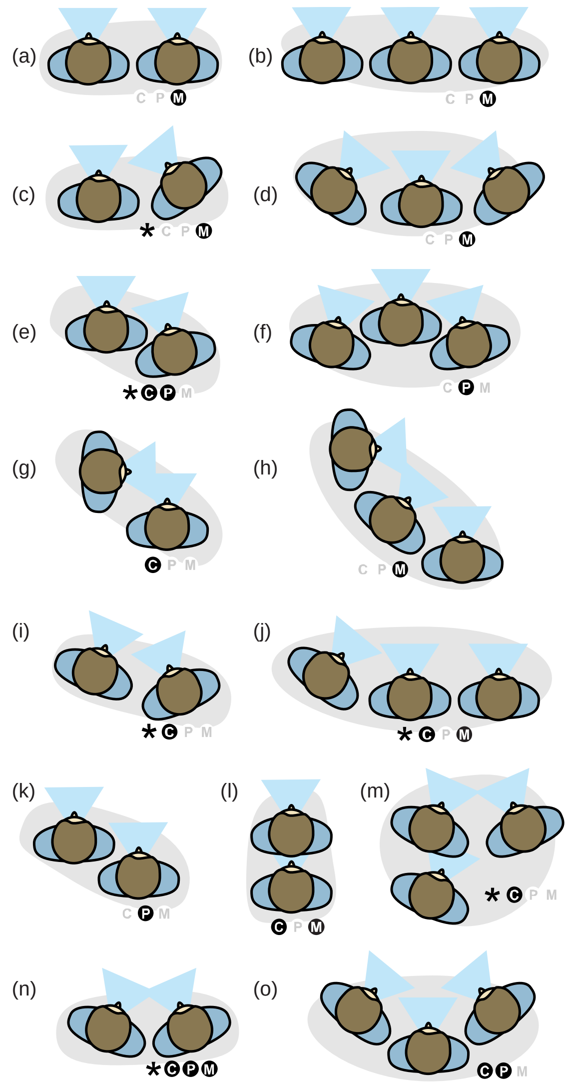


**Figure 3.3:** Assembly formations.

### 3.3.1.2 Interaction Stage Behaviour

The interaction stage begins when at least one member of the group engages the device. This stage encompasses more than group formation, so we also recorded how the group interacted with the system. For PHOTO and CINEMA settings, interaction was with the touch screen, but for the MALL setting we define interaction more broadly, as a directed gesture towards a display item, even without making physical contact. We call the primary member who is interacting, the *driver* [29], and the other members, *observers*. In all PHOTO cases, the first member to arrive became the driver, at least initially. With CINEMA, occasionally the second or third member to arrive became the driver. In simultaneous approaches, there was no way to predict who would become the driver. By definition, observers do not interact directly, but an observer closest to the display would often point and guide the driver. We define these observers as *active observers* rather than *passive observers* who did not interfere or contribute. In the MALL setting, there were more active observers due to the large display space and informal style of gesture interaction which often led to multiple members gesturing simultaneously blurring the distinction between driver and active observer. However, when a person approached the MALL display to touch it, others became passive. In fact, even when multiple groups were present, only one person would touch the display at a time.

Group formations sometimes morphed during interaction, similar to how assembly formations changed to accommodate latecomers. For example, an asymmetric assembly formation generally formed because of passive observers. An extreme example is Figure 3.3h, where a member positioned himself perpendicular to the MALL display, ignoring the display to maintain eye contact with other members. However, these asymmetric formations often morphed to symmetric ones as passive observers become more receptive of the display and sometimes fully transitioned to become an active observer (depicted in Figure 3.4). In PHOTO, passive observers often became wanderers when in a group-of-two formation like Figure 3.3k. In this case, the formation typically did not morph as members held their positions (Figure 3.3e, k) until the wanderer returned. Wanderers were less frequently seen with groups of three and in the CINEMA setting. No wanderers were noted in the MALL setting.

Although the driver was the dominant interacting member, we observed cases where active observers became drivers, especially in the PHOTO and CINEMA settings. In fact, in nearly half of the groups, the driver role changed one or more times. We call this a *role rotation*. We recorded more role rotations in the PHOTO setting, so task duration and complexity likely influence whether this rotation occurs and how often. In most cases, the formation morphed dramatically during a role rotation, especially for groups of three. For example, two women at the CINEMA setting started in the formation shown in Figure 3.3e, but after the first driver obtained her ticket, a dramatic morphing took place to change to the formation in Figure 3.3g. The small interaction space with these kiosks is certainly a contributing factor. With the exception of one group of three, the relative left-to-right ordering of group members remained the same.

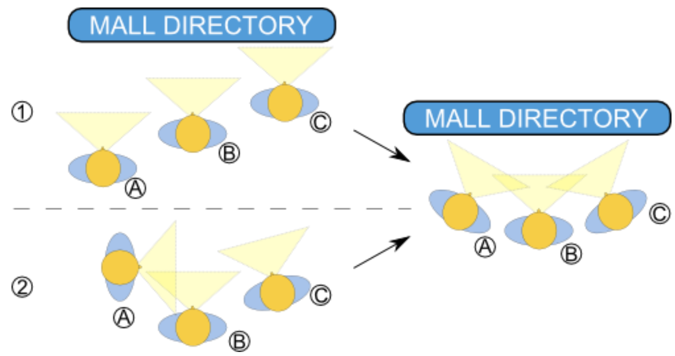


**Figure 3.4:** Asymmetric group layouts typically morphed as initially uninterested people gradually engaged the display.

In the MALL setting, group members most often interacted by pointing and touching, but also used verbal communication. To prevent gesture miscommunication, fingers were brought closer to the display to reduce parallax. Since groups of three generally stood just beyond of arm's reach, this meant that members leaned in slightly when gesturing.

### 3.3.2 Inter-group Behaviours

The observations above focus on behaviours within a group, but other groups and individuals modified these behaviours and introduced inter-group behaviours.

The density of people around the display affected group behaviour. Higher densities forced group members closer together, triggering formation morphing (e.g., such as Figure 3.3c,i to Figure 3.3k), but it drastically decreased the likelihood of a passive observer becoming a wanderer. In PHOTO and CINEMA, when adjacent kiosks were occupied, groups were naturally forced together. Rather than pairs being forced next to each other, the observer typically moved to a position behind the driver and peered over their shoulder (typically on the right as in Figure 3.3e). With groups of three, members more often squeezed the current formation tightly together.

Since the MALL display was large and shared among multiple groups, it provided the best source for multi-group formation observations. Most of the multi-group interactions were between two groups. Groups of any size, including individuals, would stagger their positions in front of the display (Figure 3.5). This formed a queue of sorts, with the first group to arrive standing closest, and the last group standing the farthest away. Similar to how members in a single group morphed their formation, multiple groups also morphed their inter-group positions. The parting of one group resulted in other groups all repositioning themselves such that they were redistributed evenly. The adjustments were minor movements: sufficient for a screen of this size.

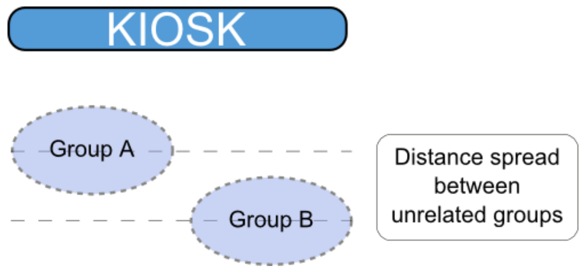


**Figure 3.5.** Multi-group positions at MALL: groups staggered their position according to arrival order.

Groups often asserted their collective interaction space with respect to other groups. At PHOTO and CINEMA settings, a group would approach a free kiosk even if members of another group were infringing on the free kiosk's space. By approaching the kiosk, the infringing group would naturally reorient themselves and compressing together into a tighter formation. This did not occur as naturally in the MALL setting. Without a clear delineation of designated kiosk workspaces, groups around the single shared MALL display could not assert their intention to interact at a particular location. This resulted in the queuing formation discussed above.

## 3.4 Discussion

This study provided rich insight and analysis into how people interact with commonly-used public kiosk installations. Positional layouts and orientation of groups and group members were manually logged during the entire course of interaction: from approach, to usage, to departure. It was seen that certain conclusions can be drawn based strictly from observations of inter- and intra-group positioning and orientation. Namely, group and role identification becomes almost trivial to deduce with the aid of a computer vision system. Smart interfaces stand to benefit from this feature to tailor UIs "on to fly". Furthermore, observing the large mall display revealed a key limitation to parallelizing use brought on by social etiquette: when a group is already engaging a display, it's more socially expected that you "wait your turn" than to squeeze in and share a single resource. With this knowledge, a design where groups are explicitly allocated workspaces *by the system* may perhaps remove this limitation. After all, when small-screen kiosks were directly adjacent to each other, groups had apparently no problems cramping themselves together. Evidently, a system's design can manipulate people's behaviour and establish its own governing etiquette.

While these observations provided valuable insight into territoriality and behaviours around existing public kiosks, there are certain caveats to address. The envisioned model of an interactive publicly-shared large-screen display is only partially based on these kiosks. At the very least, none of the observed kiosks supported collaboration to any extent by nature of their restrictive single-touch displays. Furthermore, parallel use by multiple groups was only afforded by a non-interactive display. This motivates a follow-up controlled study in order to answer questions on parallel collaboration.

# Chapter 4
# Controlled Experiment

The observational field study in Chapter 3 focused on behaviour *around* public kiosks and displays. To fully realize design implications for workspace management, we also need to understand behaviour *on* the display. The goal of this experiment is to investigate how concurrent individuals and groups use a large interactive display. To extend our field study, we focus on people's behaviour and interactions in the workspace *on* the display, paying specific attention to how those actions affect people's behaviour around the display and how the territories they adopt on the wall extend to the space around them. A controlled study not only allows for more easily monitoring users' actions on the screen, but also allows for control over a number of other factors.

This follow-up study permits two other variables to be controlled: group size and task complexity. As this study focuses on parallel collaboration on a shared display, group size undoubtedly becomes a strong influence on behaviour. We control group size so that observations of non-collaborating individuals and those of collaborating pairs can be compared and contrasted. This will clearly show the differences that prop up when collaboration takes place. In addition, the tasks given to participants can be chosen to simulate possible real-world scenarios. Thus, it helps here to exercise some creativity and imagination in devising some possible real-world software applications for such large vertical shared displays. This thesis focuses on the running example of building up an itinerary or other plan when at an amusement park. Alternatively, however, one can imagine other scenarios, such as enabling each member of a group to join in on the manipulation and selection of photos to print at a photo-developing kiosk whereby all their choices can be unionized and collectively submitted as a single purchase order. Notice that already these two sample tasks demand different degrees of teamwork. Creating a single shared itinerary, on the one hand, requires constant communication and synchronization between collaborating group members. On the other hand, the selection of photos to print can be done completely independently and merged only at checkout. This study acknowledges this versatility and uses a puzzle-solving task in various configurations which encourages different levels of group dynamics.

## 4.1 Experimental Design

In this experiment, multiple participants solved a series of real jigsaw puzzles in parallel, as two individuals or as two pairs. The puzzles were held by magnets onto a large vertical whiteboard. We chose a physical medium rather than developing a custom application on a digital large display to avoid potential confounds from interaction design, input quality, and display resolution. A puzzle task is easy for participants to understand and helped us to rapidly prototype different study designs. Most importantly, solving a puzzle requires different kinds of personal, semi-public and public tasks like assembly, sorting, and monitoring an image of the completed puzzle.

### 4.1.1 Apparatus

Six jigsaw puzzles, two of which being duplicates, were fitted with magnets to enable vertical assembly on a magnetic whiteboard. Five puzzles had 24 pieces and measured 38 x 28.5 cm. The sixth puzzle had 46 pieces and measured 91 x 61 cm. We used this as a larger workspace task to accommodate four collaborators working together. All puzzles were designed for young children (ages 3+) and depicted popular cartoon characters.

The whiteboard was divided into 2 horizontal regions. The top displayed a target image: a photo of the completed puzzle. The lower region provided 300 x 207 cm of common space to complete the puzzles (Figure 4.1). At the beginning of each session, the upper portion of this common space held the unsorted puzzle pieces. This layout approximates the “public in the top” and “private in the bottom” structure used in related public display prototypes [42].

**Figure 4.1:** Two pairs working collaboratively on the large shared jigsaw puzzle task.

### 4.1.2 Task

Two SINGLE participants or two PAIRS of participants, solved jigsaw puzzles in 5 layout configurations ranging from none-collaborative to highly-collaborative (Figure 4.2):

- SIMPLE: pieces of two different puzzles are placed directly below corresponding target images. This forms a non-collaborative baseline.
- CRISSCROSS: pieces of one puzzle are below the corresponding target image of the other. Depending on inter-group pre-planning, this requires some negotiation.
- MIXED: pieces from two puzzles are mixed together. This may require negotiation and collaboration to organize and sort the pieces.
- DUPLICATE: pieces of two identical puzzles are mixed together. This requires more collaboration to organize and sort pieces without hoarding or stealing.
- SHARED: One large puzzle is completed collaboratively by both SINGLES or both PAIRS. This requires a high level of collaboration.

Participants were told that the experiment was not a race, and that there was no incentive for finishing first.

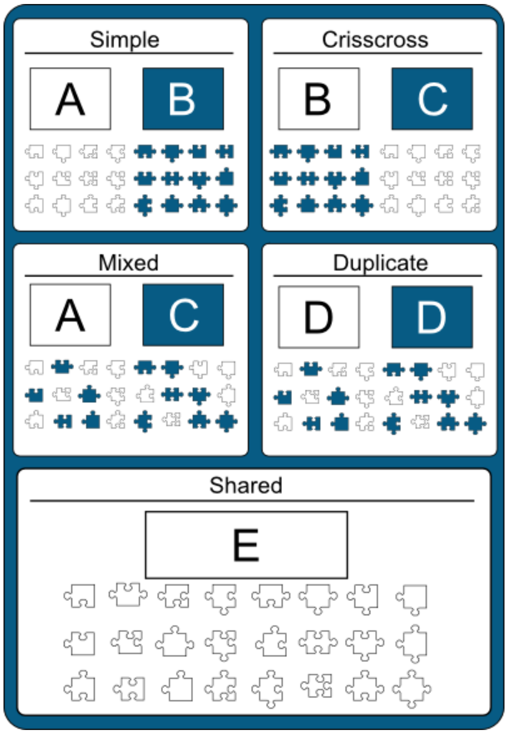


**Figure 4.2:** Puzzle layout configurations (‘A’ through ‘E’ represents a unique puzzle).

This task was designed to closely emulate a typical computing task that would appear on such a system. It requires users to progress through a relatively simple task of grabbing “bits of information” and piecing them together to create an overall constructed picture: a goal state. This is analogous to planning an intraday itinerary from a potentially lengthy list of events occurring at a large amusement park or convention center, for example. Moreover, it demands this need for users to establish their personal territories (workspaces) dynamically on the display’s finite real-estate to separate their own assembly from the shared, or communal, information represented by the unclaimed jigsaw pieces.

### 4.1.3 Participants

30 adults (16 females) were recruited by e-mail from the university’s graduate population to participate in the study. 10 participants were designated as SINGLES and 20 were grouped into PAIRS such that each pair had two people with a pre-existing social or professional relationship (7 were opposite-sex pairs).

## 4.2 Data Collection and Analytical Method

There were 10 experiment sessions (5 SINGLES and 5 PAIRS). Each session had 5 trials: 1 for each layout configuration as defined in Figure 4.2 counterbalanced using a random Latin square. Between trials, participants were asked to leave the room so they could not see the puzzles being set up. While outside the room, they were also asked to refrain from any inter-group communication. At the conclusion of each session, participants were asked to fill out a short survey based on their experience. The survey gauged participants' level of engagement, fatigue, and willingness to share the display on a 5-point Likert scale and collected any relevant comments they may have had.

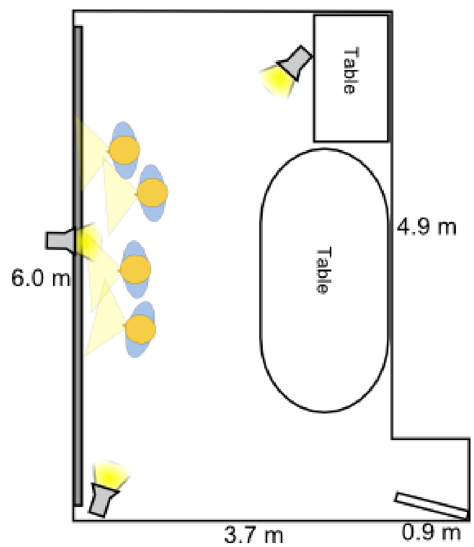


**Figure 4.3:** Study room's layout indicating 1) room dimensions, 2) the three camera positions, 3) entranceway, and 4) position of whiteboard.

All 10 sessions were audio and video recorded. Video was captured from three different angles: overhead, side, and rear as illustrated in Figure 4.3. Video from each angle were synchronized and composited together to create a split-screen view (Figure 4.1). Each session lasted 34 minutes on average (SD = 13, RANGE = 27 – 71), creating close to 6 hours of video for analysis. Qualitative analysis used an open coding approach based on Strauss and Corbin's Grounded Theory Methodology [39] (Figure 4.4).

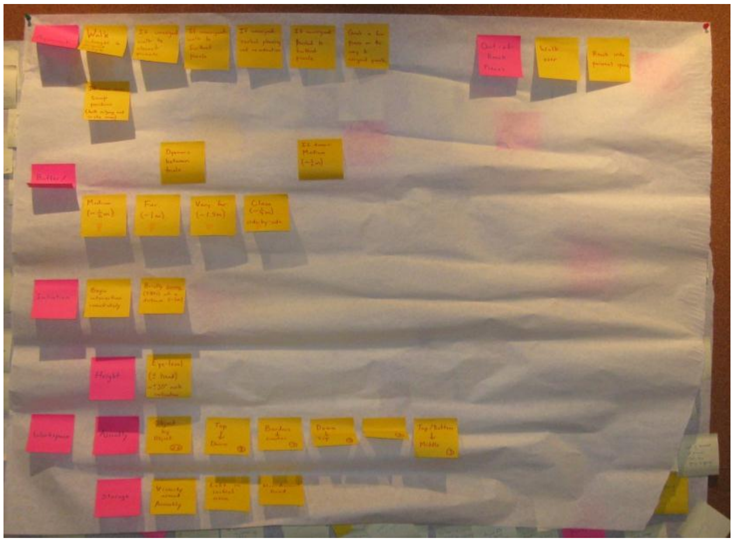

**Figure 4.4:** Axial coding: concepts (pink) and codes (yellow).

## 4.3 Results

We present our observations in three sections. Behaviour *on* the display focusing on workspace territory, behaviour *around* the display focusing on formations of participants when interacting, and behaviour which bridges *on* and *around* display territories.

### 4.3.1 On-display Behaviour

On-display behaviour is primarily concerned with individual and group workspaces, defined as the display space used for the *majority* of the task. Analogous to Scott *et al.*'s findings for tabletops [37], participants partitioned their workspace into three territories: personal, storage and public (Figure 4.5). As participants completed the task, their territories grew and shrank, but we noted distinct patterns.

For the most part, PAIRS collaborated in solving the challenge. Only in one DUPLICATE layout trial with the PAIRS condition, one pair opted to complete two halves of a puzzle independently then merged at the end.

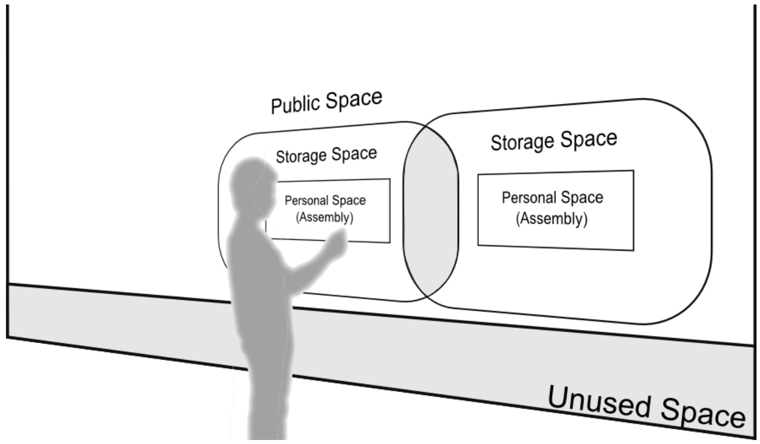


**Figure 4.5:** Three workspace territories: personal, storage, and public space. Note intersection of storage space is shared with adjacent individual and space below waist is unused.

#### 4.3.1.1 Personal Territory

The region dedicated to actual puzzle assembly becomes a *personal territory*. Since the puzzle's size grows as it is pieced together, we define this region as the bounding box around the area of construction. Since puzzle assembly occurred at eye-level, this space was the portion of the display closest to the face (a very personal area) and spanned within arm's length falling comfortably within 0.5 – 1.2 m which matches Hall's definition of personal space [15]. We observed no intrusions into this area by the other party in both SINGLES and PAIRS trials.

#### 4.3.1.2 Storage Territory

Immediately outside the personal territory marks the start of *storage territory*. We frequently observed SINGLES and PAIRS relocate pieces to a temporary holding area near their personal territory. These were often pieces which were likely to be used next, but we also observed participants test the compatibility of a small subset of pieces in this space rather than their personal territory – using it as a kind of sandbox. The boundary of storage and sandbox territory is less defined than personal territory. In our puzzle task it extended the width of two pieces.

Unlike personal territory, storage and sandbox territory would sometimes overlap, becoming *shared storage*. This was used to transfer or exchange pieces frequently: an average of 15.8 times per session (SD = 11.8) for SINGLES and 16.8 times (SD = 10.8) for PAIRS. Like personal territory, intrusion into unshared storage territory was very infrequent: an average of 0.4 times (SD = 0.9) per

SINGLES session and only once in 4 PAIRS sessions each. There appears to be an expectation that the shared storage which forms between two nearby workspaces can be almost exclusively used for transferring ownership of information.

#### 4.3.1.3 Public Territory

All space beyond the storage territory was considered *public territory*, a communal territory. We observed participants freely interact in this space without verbal or non-verbal negotiation which suggests that this space is implicitly assumed to be available for anyone. Most obvious in MIXED, SHARED, and DUPLICATE configurations, multiple participants handled the same piece, as long as it was returned to the public territory. If a piece was taken and later replaced (e.g., deemed unnecessary, not enough storage space) that piece was assumed to be available to everyone again. Very infrequently, public territory served as an ad-hoc storage space to test the compatibility of pieces in a vacant area: three SINGLE individuals and one PAIR used this strategy once.

### 4.3.2 Off-display Behaviour

As participants interacted in these territories on the vertical wall, they organized themselves into a variety of formations. We describe the results of four aspects of these formations: the *initial formations* that participants chose when beginning interaction, the *settled formations* which they worked in for the majority of their time, the *initial interaction* which marked the start of interaction, and the *buffer zones* they maintained between each other.

#### 4.3.2.1 Initial Formations

At the beginning of each session, all but two participants immediately approached the display and took a position to begin interacting. As soon as the final participant stopped, the formation of all participants was documented as an *initial formation* (Figure 4.6). The SINGLES condition could only take one formation as both participants reached the display, but PAIRS had more initial layout variations (Figure 4.6a).

#### 4.3.2.2 Settled Formations

We define a *settled formation* as the formation held longest or most frequent while interacting. While SINGLES had the same initial and settled formations, PAIRS quickly and fluidly morphed from an initial formation into an often completely different formation (Figure 4.7). Within a pair, the two individuals typically held their relative left-to-right positions, but rarely demonstrated a rotation just like we saw with groups of two in the field study, namely for PHOTO and CINEMA.

#### 4.3.2.3 Initiating Interaction

Participants did not always immediately begin interaction after having approached the display and established an initial formation (refer to 4.3.2.1). Seemingly more cautious individuals first surveyed all the pieces in an attempt to first decipher the challenge they were presented with. This characteristic was coded: if a participant delayed more than three seconds at the display before his/her first interaction, that approach was marked as being cautious, otherwise, not. Of the 50 instances in the SINGLES track (5 sessions × 5 rounds × 2 participants), 18 cautious approaches were observed. The remaining 32 began interaction immediately. This behaviour may resemble what would happen with inexperienced users presented with a new and unfamiliar interface. With team members arriving at the display asynchronously in PAIRS, interaction often began *before* the initial layout (Figure 4.6) was achieved. In other words, participants sometimes would begin interaction immediately even if their partner had not yet arrived. A cautious team approach was coded if three seconds of no interaction had elapsed from the time the *first* team member arrived. Of the 50 instances in the PAIRS track, 16 cautious team approaches were identified. The remaining 34 began interaction immediately. The longest delay exhibited by any team was six seconds (to the nearest second).

#### 4.3.2.4 Buffer Zones

In contrast to tabletops, users of vertical displays have more freedom to move around. As participants collaborated on the display, their workspaces evidently grew and shrank over the duration of the task. In earlier stages, for instance, storage spaces were much larger and gradually shrank and became more defined as the puzzle was being completed.  The distances between groups of SINGLES and PAIRS were coded in an attempt to uncover the social norms, if any, pertaining to maintaining personal space territories while engaging a device.

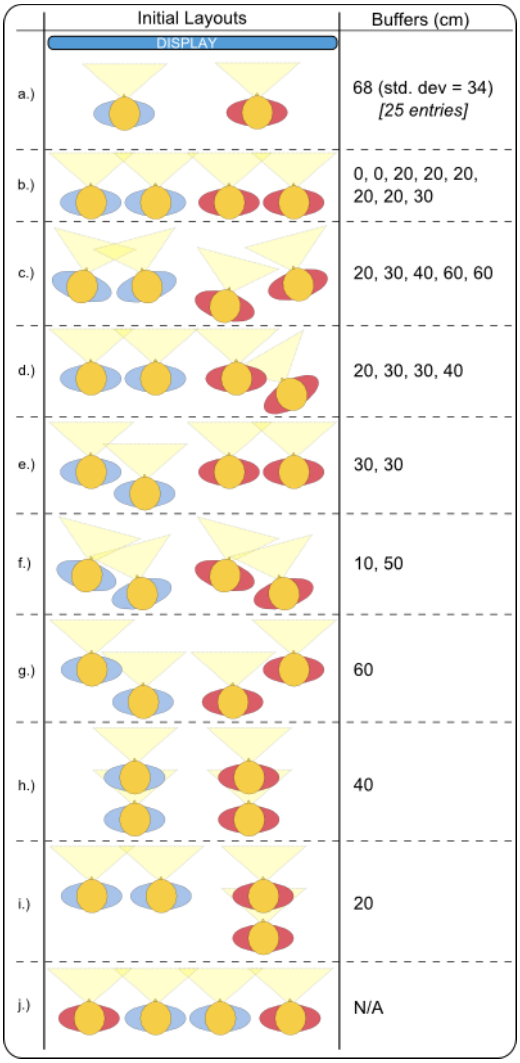


**Figure 4.6:** Initial formations and buffer sizes for all 50 trials. A buffer size of 0 cm indicates physical shoulder contact.

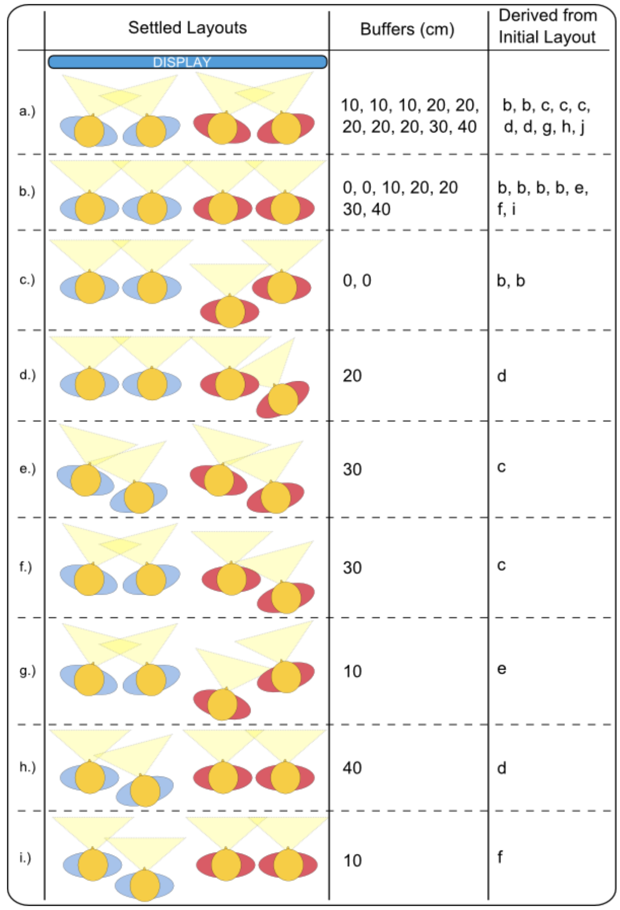


**Figure 4.7:** Settled formations and buffer sizes for all 25 PAIR trials. The initial formation leading to settled layout is included (refers to Figure 4.6).

We quantify inter-group formations by measuring the smallest lateral distance between the feet of participants in different groups when participants are within arm's length of the display (Figure 4.8). We call this the *buffer*. Visual markers in the scene enabled us to measure the buffer with 10 cm of precision. We logged a new buffer size whenever a participant moved to a new location for at least three seconds to filter out natural brief movements. It was determined that SINGLES maintained an average buffer zone of 61.0 cm (SD = 33.4cm) and displaced themselves an average of 5.36 times (SD = 5.87) per trial. PAIRS maintained an average buffer zone of 28.3cm (SD = 22.8cm) and displaced themselves an average of 2.96 times (SD = 1.97) per trial. SINGLES evidently took advantage of the additional space and were generally more spread out and consumed more storage.

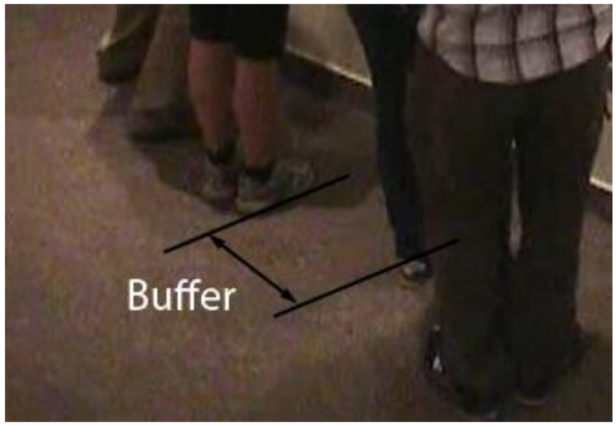


**Figure 4.8:** Defining the buffer zone.

### 4.3.3 Combined On- and Off-display Behaviour

Puzzle pieces could be widely dispersed in the MIXED, SHARED, DUPLICATE, and CRISSCROSS configurations. In these cases, pieces could be out-of-reach for a participant. Retrieving these pieces often required negotiating both on- and off-display space. Since we are interested in behaviour among groups, we only coded out-of-reach pieces when they were beyond the participant's reach and within reach of the other party. There were 37 out-of-reach pieces for SINGLES, with an average of 7.4 per session (SD = 3.8). There were 45 out-of-reach pieces for PAIRS, with an average of 9 per session (SD = 4.6). We identified three out-of-reach retrieval strategies:

1. *Walk-and-grab*. SINGLES always chose to walk over and grab pieces, even if it intruded in Hall's 0.5 m intimate space [15]. Participants in PAIRS chose to walk over and grab for 38 of 45 instances (84%).
2. *Ask Other Party*. Participants in PAIRS requested assistance from the other party using verbal or non-verbal communication 3 times.
3. *Ask Partner.* Participants in PAIRS requested assistance from their partner 4 times. The initial arrangement of jigsaw pieces had far more out-of-reach pieces than the numbers above indicate. In practice, when participants identified a piece belonging to the other party, they largely discarded it into the shared storage space territory (refer to 4.3.1.2).

## 4.4 Perceived User Experience

Participants were asked to complete a short anonymous survey at the conclusion of their session. It consisted of three questions designed to gauge overall sentiment, albeit loosely, using a 5-point Likert scale (5 represented Strongly Agree):

1. I felt engaged by the task by solving it on a vertical display
2. Sharing the workspace did *not* bother me
3. I felt fatigued at some points in the session

To contrast the sentiments of both SINGLES and PAIRS, track averages were computed in addition to a final overall average and included in Table 4.1:

| Question | SINGLES | PAIRS | Overall |
|---|---|---|---|
| **1** | 4.10 (σ = 0.74) | 4.05 (σ = 0.89) | 4.07 (σ = 0.83) |
| **2** | 4.00 (σ = 1.05) | 4.15 (σ = 0.88) | 4.10 (σ = 0.92) |
| **3** | 1.80 (σ = 1.14) | 2.35 (σ = 1.18) | 2.17 (σ = 1.18) |

**Table 4.1:** Gauging perceived user experience.

T-test calculations for all three questions showed no statistically significant differences for SINGLES and PAIRS. Thus, regarding overall sentiments, participants agreed (4) that they felt engaged by the display. There was also an agreement (4) over their willingness to share a display with others. A somewhat less optimistic sentiment was reached for fatigue: while the consensus disagreed (2) that a level of fatigue had been reached, they did not strongly disagree. Considering a standard deviation of over 1, this may hint at some early signs of discomfort being encountered by a small subset of participants.

### 4.4.1 Participant Comments

Participants were also asked to optionally provide any additional comments in writing. The most common comment, occurring five times, was a dislike about having to constantly look up at the ambient portion of the display. Two other participants complained about their arms getting tired: the notorious gorilla-arm effect[3]. One participant showed a strong distaste for working in parallel. However, six participants explicitly stated that they found the experience enjoyable.

[3] The undesired side-effect discovered in the early 1980s of experiencing fatigue and soreness in the arm with prolonged use of vertically-oriented touch-screens [34].

## 4.5 Discussion

The study in this chapter extended many of the concepts in Chapter 3, namely, off-display territories, to including observations of both collaborating and non-collaborating groups working in parallel on a shared display. A catalog of formations was built documenting the physical layouts likely to occur including details regarding buffer zones maintained by non-collaborating groups. Non-collaborating singles took advantage of the extra space and spread out and held only infrequent, very brief conversations. It was interesting to observe that groups, however, *could* have spread out much more than they did, suggesting people are much more comfortable being squeezed together with unknown parties when groups are involved. They were also noted to engage in much more casual inter-group conversation. It would be interesting to see which of these extremes (or middle-ground) would take place if a PAIR was sharing the display with a SINGLE – a limitation of this study.

This study also introduced many new concepts. On-screen territories were difficult to observe "in-the-wild", however, made feasible with a controlled study. It was found that Scott's [37] tabletop findings of on-screen territories transferred well to vertical displays with few modifications. Namely, personal, storage, and public territories became increasingly well-defined as a task progressed. Groups never trespassed into other groups' personal territories as defined by the bounding box around a "work in progress", however, storage territories suffered intrusions on a few accounts. A notable difference with non-collaborating groups using the space in parallel revealed that overlapping storage territories *in-between* group workspaces was implicitly agreed upon to be used as shared storage instead: a transfer medium to exchange puzzle pieces. It now remains unclear what would happen if three groups were sharing the display: would the group in the middle refrain from using either side as storage and be forced to use only the top and bottom portions? This is another limitation of this study.

Stand-up-and-use systems drain more physical energy from their users, especially when contrasted with sit-down-and-use tabletops, for example. It was clear from participant feedback that early signs of fatigue were surfacing by some participants following the 30-minute sessions. Both the gorilla-arm effect was noted as well as neck strain from repeatedly referencing the top portion of the display. This is an obvious weakness of these systems and so this limiting factor should be respected when choosing what tasks to support collaboration for.

The combination of on- and off-screen observations of behaviour from both studies can be used to suggest a descriptive framework for designing large vertical publicly-shared displays.

# Chapter 5
# Design Implications

Recall our motivational scenario of a large interactive display for groups to plan their day at an amusement park (Figure 1.1). In this scenario, a large, public, interactive display is being used by multiple independent groups in parallel.

More generally, the design of large, public, interactive displays may be designed around a number of multi-user arrangements. For example, one user could drive the entire interaction, or many users could interact in parallel. User's tasks could be almost completely independent (loosely coupled as in the amusement park scenario) or they could be related and collaborative (i.e., tightly coupled, such as trivia content prior to a movie in a theatre). The tasks for which interactions are designed may vary extensively in length.

The goal of this thesis is to understand the use of territory both around and on large, public, vertical displays. Once understood, the next salient question is how these observations relate to the design of such systems. More particularly, how should territory, both on and around the display, be used to infer information about users and to influence the behaviour of users? Consider, for example, the following scenarios. With the aid of already-existing computer vision techniques, if systems can recognize the positional distribution of people in the immediate vicinity and by employing the results obtained in this thesis as leverage, interfaces can dynamically and fluidly adapt to their surroundings. Consider recognizing when two people are approaching an interactive display and having a workspace wide enough to accommodate both of them exactly; same for three people, and so forth. Now we may extend this novel solution to recognize when a group member is standing slightly behind “the driver” indicating a lower level of awareness or interest to interact with the content on the display. The workspace may now safely shrink freeing resources for others.

This chapter discusses some key features that designers of public vertical surfaces should consider and/or future researchers may want to explore. Given that two studies were conducted, we separate and present the guidelines based on the results of each study. While the guidelines presented in this chapter are biased towards large vertical publicly-shared displays, keep in mind the alternative applications mentioned above.

## 5.1 Field Study Design Implications

In our field study, user behaviours around kiosks and directories were observed. These observations provide evidence that information about users can be inferred by observing users and that these inferences can then be used to design interactions. In this section, group and role identification are discussed. Next, once groups and roles are identified, we demonstrate how this information can be used to inform on-screen territories, and how on-screen territories can be used to manipulate end-users.

### 5.1.1 Group and Role Identification

#### 5.1.1.1 Group Identification

Our catalogue of typical group arrangements when approaching and interacting is a first step to implementing an automated group identification algorithm. Delayed approaches by some members and wandering members while interacting make this a difficult problem. It was generally a trivial task to identify a group of two; however, as group size increased, the number of variations of approach quickly grew and made this task very unpredictable. In fact, with delayed approaches becoming introduced with groups of three on more complex tasks, group size is a very dynamic variable and must be continuously accounted for throughout interactions.

Multiple groups further complicate the matter. For ambient displays, distinct social groups tend to position themselves as a depth-based queue. This, in conjunction with orientation of members and facial cues may be used for group identification. With that said, this study cautions against the use of facial cues and eye contact alone to infer groups. While its existence can assist in group identification, its absence does not imply unfamiliarity between members.

#### 5.1.1.2 Role Identification

Workspace characteristics should adapt according to different member roles. The driver may be given the primary space, then active observers, and less so for passive observers. Role rotations should be expected and accommodated smoothly, especially during long tasks.

### 5.1.2 Group Workspaces

Once groups are tracked and roles identified, the system can manage group workspace territory more effectively. In this section, we argue that territory can be allocated and re-allocated to account for changes in the size of individual groups of users and to influence the behaviour of groups.

#### 5.1.2.1 Dynamic Workspaces

Users in groups may approach displays asynchronously. The longer and more complex the task, the more likely wandering and a delayed approach would occur (i.e., member(s) of a group joining well into the interaction). These delays can range from a couple seconds to several minutes, depending on the task. It would be required that any virtual workspaces on large-screen displays be dynamically sized if collaboration is to be supported. This would also address wandering behaviours.

An asymmetric group layout (Figure 3.3h,j,m) was a good indicator that one or more members of a group were unengaged with the display. As an unengaged group member gradually became more engaged, we noted transitions in their layout in front of the display; an indication that intra-group parallel interaction was about to increase. If space allocation on large screens was dynamic, then changing orientations of groups could fluidly be supported. As more members focus on the display, more space could be allocated.

This study also showed that as tasks became more complex and real-estate was available (in this case, in the form of a vacant kiosk), individuals may break away from their group and explore independently. Because group members occasionally break away, interact alone, and return, shared public screens should be designed to support this fragmented collaborative style.

#### 5.1.2.2 Influencing Buffer Zones and Group Density

It was immediately obvious that people, even within a social group, preferred to maintain a certain amount of buffer zone between each other. This was evident from the wide-spread layouts in Figure 3.3b,h,o which occupied the largest area in front of a display and was exclusive to the large-screen mall display since it was the only setting that could afford it. The study showed that territoriality can be influenced by the system itself – to a small degree. Compression in the size of the screen real-estate (large mall display down to smaller kiosk) would result in group members squeezing together; however, with the caveat that there was clearly a sensitive threshold where if the compactness of users became too demanding to maintain, wandering of group members may result.

#### 5.1.2.3 Pointing versus Touching

There is a semantic, profound difference between pointing and touching. Users who point are communicating ideas within a social group and may not want the technology to treat it as input. This is more of a cautionary note for hover and/or gesture detection.

#### 5.1.2.4 Leveraging Group Territoriality

Inter-group behaviours motivate the potential benefits of dynamic territoriality. At small-screen kiosks, groups approach a free kiosk even if another group is infringing on the space in front of the free kiosk. Stepping up to a free kiosk asserts territoriality, and the group that was infringing on the workspace around the free kiosk naturally reorients themselves, both by compressing together and by repositioning members close to the free kiosk. This tacit negotiation or territory between groups was, however, poorly supported by the mall directory. When a second group approached the mall directory, there was no indication of their presence, so no space was made for concurrent use. Instead, later arrivals would wait until the current group moved before approaching the display. Based on this tacit negation of territory, territory could be used to promote concurrent use by un-related groups. If displays were made aware of their environments, i.e., displays could recognize prospective moving from the implicit to subtle zones of interaction [24], and then the display could signal groups of users in the personal zone of interaction by shrinking and/or repositioning territory.  This would support the natural dispersions and compressions that occur as additional groups arrive at shared screens. It seems reasonable to consider territory a resource that can be used to maximize concurrent use by and between groups.

#### 5.1.2.5 Session Suspension versus Termination

We noted that inter-group communication took place when a group temporarily left their kiosk to assist another group struggling with their display. As a result, it would be presumptuous to mark the conclusion of a group's interaction session solely based on a physical departure from the system. If the system could recognize when users are interacting with other groups, this could allow elegant discrimination between situations where suspension versus termination of groups' sessions is most appropriate. Furthermore, a method of censoring the display's contents would be advisable in the case of suspended interaction, depending on the context.

## 5.2 Control Study Design Implications

The controlled study provides additional information which can be leveraged during the design of large public displays.  These include additional information on group interactions around the display, specifically between-group buffer distances and a catalog of inter-group and intra-group formations. The controlled study also provides observations of on-display behaviours as well as shedding light on the limitations of task complexity pertaining to stand-up-and-use systems.

### 5.2.1 Multi-group Interactions around the Display

Our quantitative results for buffer distance between groups and expanded catalogue of intra-group and inter-group formations extend information pertaining to *Group Identification* (refer to 5.1.1.1) and *Leveraging Group Territoriality* (refer to 5.1.2.4). Our results extend these implications by introducing the behaviour of concurrent individuals: they are less stationary than a group of two, they avoid information communication to retrieve distant information, and they seek a larger buffer zone. Likewise, the confirmation of left-to-right order preservation for group members, even when reaching for distant information, extends our understanding of *Role Identification* (refer to 5.1.1.2). However, the primary contributions from this study are for on-display workspace design.

### 5.2.2 On-display Workspace Design

#### 5.2.2.1 Three Types of Workspace Territories

We found strong support for the kind of territoriality observed on tabletops on large displays. In other words, a system should support personal and storage territories within the common public space, keeping in mind their respective functions. In addition to being a place to gather information, the storage territory will likely also be used as a sandbox, to test out temporary information transformations before committing to the personal space. This sandbox territory should also be supported ad hoc in the public space. Finally, the natural tendency for adjacent groups to use a shared territory can be formalized and leveraged.

#### 5.2.2.2 Workspace Size and Location

Workspaces should be located near eye level of an individual or average group member height. This minimizes neck strain, especially for longer tasks. The personal territory can be sized tightly to the expected size of assembled information and the shared territory can be sized to hold a relatively small number of information items and wrapped tightly around the personal territory. No interaction should be expected below the waist.

To mimic a system which affords both interaction as well as preserving ambient information for more distant passers-by (Figure 1.1), the design of the puzzle experiment split the display into a lower interactive portion and an upper ambient display which housed an image of the completed puzzle for reference. In their feedback, two (of 30) participants from the control study explicitly remarked some exhaustion in the neck from having to constantly look up at the reference puzzles. This feedback discourages having any dependency on information in the ambient portion for users interacting on the lower portion.

#### 5.2.2.3 Reaching and Sharing

If information is located away from an individual, they will reach for it themselves, even if this requires walking. This suggests that techniques that support virtual reaching (e.g., the virtual reaching technique in [42]) are beneficial. However, we also found that informal, almost accidental sharing using the shared storage territory occurs often. If individuals that temporarily take an item, only to realize they do not need it, will silently pass it to adjacent groups if the system makes this sharing convenient.

### 5.2.3 Task Complexity and Fatigue

An important consideration when designing software applications for these systems is the level of complexity involved with using them and how long a typical session is expected to run. A stand-up-and-use system is prone to more fatigue than a sit-down-and-use desktop. There are two sources of exhaustion: the legs from standing, and the dominant arm from interacting (gorilla-arm effect). From the observational study, we saw one outlier case where a session lasted 55 minutes on the photo-developing kiosk. In this case, there were frequent role rotations taking place and at one point, the driver took a break and wandered to purchase a drink and returned. This (anecdotally) hints at an upper-bound time limit for sessions. For more concrete evidence, some of the participants' feedback from the control study indicated early signs of fatigue and after 30-minute sessions. Keep in mind that participants were relatively younger graduate students as well. Thus, the applications that are deployed on these public systems should be targeting for sessions to be expected to last no longer than 30 minutes. For example, a task for collaborating to establish an itinerary for the day at an amusement park would be quick and therefore acceptable. A task which allows prospective book buyers an opportunity to read entire summaries is discouraged.

## 5.3 Discussion

The observations of the two studies presented in Chapter 3 and Chapter 4 led to the construction of a descriptive framework highlighting some design implications for the consideration of designers of large vertical publicly-shared displays and other similar systems. Evidence presented in this thesis suggests that incorporating these specifications, perhaps with some fine tuning, will boost a system's usability and, as evidenced by direct user feedback, create a more enjoyable experience. The reader should note, however, that the descriptive framework provided in this chapter only *suggests* the set of design implications outlined. Further research is required to conclude the extent of the effectiveness, if any, of these designs in influencing behaviour.

As a proof-of-concept incorporating some of these design implications, a fully-functioning high-fidelity prototype of an interactive large-screen system was designed and built demonstrating a basic painting application we called SketchPad++ (screenshot shown in Figure 5.1). Users begin interaction by touching a vacant spot on the screen which creates a new window (read: workspace) containing a blank canvas. They then have the ability to paint artworks with their fingers using a variety of colours available in a palette toolbox located at the bottom of their workspace. To close the session, they simply touch the 'x' symbol in the upper-right corner of their workspace. The task supports parallel use by multiple non-collaborating groups and its simplicity limits the risk of user fatigue.

The system was built using the Microsoft Kinect Natural User Interface (NUI) hardware for input detection, and was connected to a laptop featuring an Intel Core i7-2670QM quad-core processor (3.1 GHz) and 8GB of RAM which generously accommodated the hardware resource requirements of the application. Unlimited points of contact on a surface can be reliably determined using the embedded depth camera combined with basic image processing techniques while maintaining a smooth 30+ frames per second. Looking at the live-view of the "Depth Camera" in

Figure 5.1, hover points (shaded in red) can even be distinguished from contact points (shaded in blue) for superior application control. This is analogous to traditional mouse-over and mouse-click events in WIMP-based GUIs. The resulting image is then rendered and projected onto a wall using a standard video projector, also connected to the laptop, to altogether effectively serve as an interactive large vertical display. Installing a robust system composed of these now-common technologies in public would realize the envisioned large vertical publicly-shared display – affordable even on a consumer level.


**Figure 5.1:** Screenshot of SketchPad++: a paint program built to demonstrate one interpretation of our descriptive framework. It also shows the feasibility and accessibility to the envisioned system of this thesis (Figure 1.1). Gestures in-air (indicated by the dashed-outline box) can be translated reliably into input using the depth camera embedded in the Microsoft Kinect NUI hardware, then processed, and then rendered.

The primary characteristic of this prototype application is in its allocation of workspaces for users and groups of users. Upon session initiation, workspaces are dynamically positioned to where a user is standing based on his/her initial touch. The width of the workspace can be scaled to accommodate the group's size to support and encourage collaboration. The height was chosen to ensure sketching occurred at eye level with the colour palette outside of personal space, but within peripersonal space (arm's reach); otherwise, a more elaborate target acquisition would be required. To effectively demonstrate the concept of *leveraging group territory* and *influencing buffer zones and group density*, having well-defined workspaces via windowed canvases emulates the property inherit in closely-adjacent independent kiosks. From the observational field study, it was seen that groups had much less concern squeezing together given this environment (e.g., CINEMA) as opposed to one larger shared resource (i.e., MALL). It is hypothesized that this will alleviate the "group-queuing" inefficiency seen at mall (refer to 3.3.2). This prototype application can serve as a testbed to evaluate hypotheses associated with the effect that manipulations of on-screen territory have on group behaviours (inter/intra-group density, multi-group interaction, etc.).

The design decisions presented above are collectively just one sample solution using the descriptive framework derived in this thesis. The goal of the system was to test those specific hypotheses surrounding the effects of on-screen territories on around-screen territories. Much like the Principles of Design are a set of guidelines artists follow[4], designing around this framework is ultimately an art and each "piece" will warrant its own critique (evaluation) for effectiveness.

[4] The Principles of Design is a set of concepts used to organize and arrange the structural elements of design. They are: balance, rhythm, proportion, emphasis, and unity [22].

# Chapter 6
# Conclusion

This thesis explored the notions of territoriality and human behaviour on and around large vertical publicly-shared displays. A comprehensive literature review outlined research which investigated many tangential and overlapping areas to this space; however, it was surprising that given the encouraging motivation of this technology, this specific area has been left under-explored. To fill this niche, we presented two studies – one observational and one controlled – that examined inter- and intra-group behaviour *around* and *on* public displays.

Collectively, results from our studies informed the design of publicly-shared displays by providing insights into group identification and tracking, role identification, allocating size and location of group workspace, and group territoriality before, during, and after interaction.

## 6.1 Field Study

The field study provided detailed accounts of people's interactions with public kiosks and displays. We documented group position and orientation around existing public displays and kiosks. Strong evidence showed that the positional layout and orientation of groups and group members can be used to make inferences. Severely asymmetric group layouts with a public display, for example, was indicative that the group member(s) breaking the symmetry was highly likely to be disinterested in the display's content. A critical observation showed that parallelization of usage was limited by the social etiquette of groups to allow one group to finish their session and leave before walking up and engaging the display themselves. This was seen as groups "queued" in front of a display. This confirmed the similar behaviours Peltonen *et al.* observed with their CityWall research project [31].

Users could be classified into three categories based on their functional roles: driver, active observer, and passive observer. The driver led the progression of session while active observers collaborated via verbal and/or gestural cues. Passive observers may have watched on, but had no interaction or contributive factor during sessions. Layouts could again be used to infer roles; however, not very reliably and this task is further complicated by the fact that roles often rotated within the same session.

Task complexity also led to changes in behavioural patterns. Longer tasks, i.e., the photo-developing kiosk, exhibit both more role rotations and wandering. Both of these behaviours would generally affect a group's layout. A role rotation which exchanged a driver for a passive observer, for example, could completely alter the group's physical layout. Wanderers would typically initiate as passive observers, quite often standing further back from the display than the driver, and so their departures and returns may not affect other members at all.

## 6.2 Controlled Study

The observations from the field study were limited in the sense that existing kiosks did not wholly reflect the characteristics of the envisioned system of this thesis. Thus, this motivated the design and execution of a follow-up controlled study. In our second study, we examined group behaviour *on* the display and demonstrated that on-screen territories for shared vertical displays are similar to those observed in collaborative tabletops [29, 37]. Our results demonstrated that Hall's [15] proximity zone classification and social practices around these zones must be modified to accommodate interactions around and on a large display given the frequency and acceptability of people violating each other's personal and intimate zones. In addition, we extended prior work in territoriality to showing how the territories of groups working concurrently influence each other and how these territories change throughout the interaction.

The effects that varying task complexity and group size had on territories, both on- and off-screen, were also coded. There was a clear indication of relaxed comfort when two pairs were working in parallel contrasted against two singles. This was indicated by 1) much more cross-group conversing in two-pair sessions, and 2) the chosen placements of two singles' workspaces on the surface were generally more spread apart, diluting into the available space. Consequently, they moved around much more frequently resulting in more highly-volatile buffer zones.

User feedback gauged the overall perceived user experience as well as gave the participants an opportunity to remark on the pros and cons of solving challenges collaboratively on a vertical display. It was mentioned by the vast majority of participants (21 of 30) that the experience was overall a positive one with the remaining not feeling strongly one way or the other, i.e., neutral. There was minor indication, by seven of the 30 participants, of some light exhaustion after the approximately 30-minute sessions, specifically with the gorilla-arm effect and in the neck from having to look up at the upper-half of the wall display.

## 6.3 Future Work

This thesis presented very ground-level observations and results on how people collaborate on and publicly share large vertical displays. Having said that, this presents the opportunity for building up from this foundation.

A very inspired extension to this work would be to leverage the mobile phones existing in so many pockets as an enhanced interaction technique. This can effectively extend the input-output space from the large display. As an output device, the phone's display can show alternate views of content existing on the much larger vertical display. As an input device, the touch-screen and/or keypad can be used to manipulate data both on this alternate view, and remotely on the large display. There has been some research into using mobile phones as an extension to the input space of larger displays [16, 25, 35]. Research similar to Rekimoto's pick-and-drop technique [35], which enables seamless transfer of data between devices, are very applicable. Consider collaborating on the large display to create an itinerary or a planned route on maps. Group members can each "drag" a finalized copy to their personal phones and walk away with a portable copy. This extension would certainly add to the ubiquity of the system.

There may be some privacy concerns with sharing a display in public. For example, if a system asks for logins or other private/sensitive data, users may (should) be uncomfortable entering this data on-screen where nearby strangers may see. Extending the input space to mobile phones can help alleviate this concern by enabling users to enter them more discretely. Nonetheless, issues surrounding privacy should be investigated.

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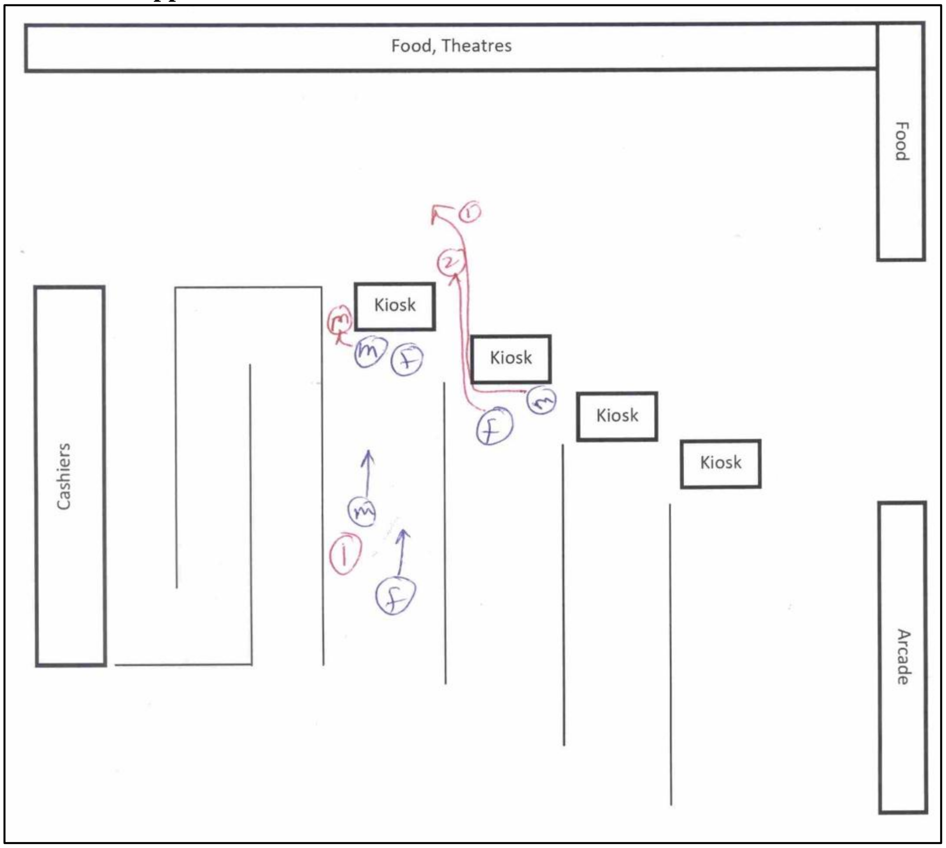
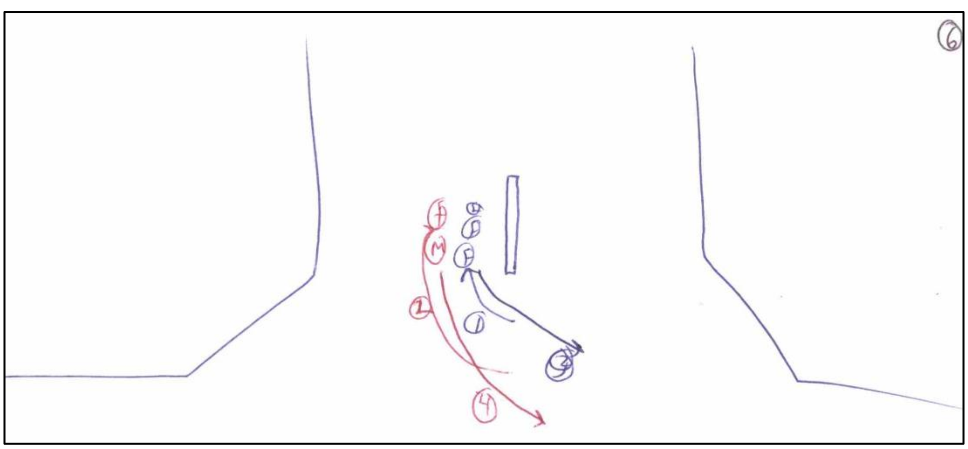
# Appendix A

## Sample Observation Study Sketches

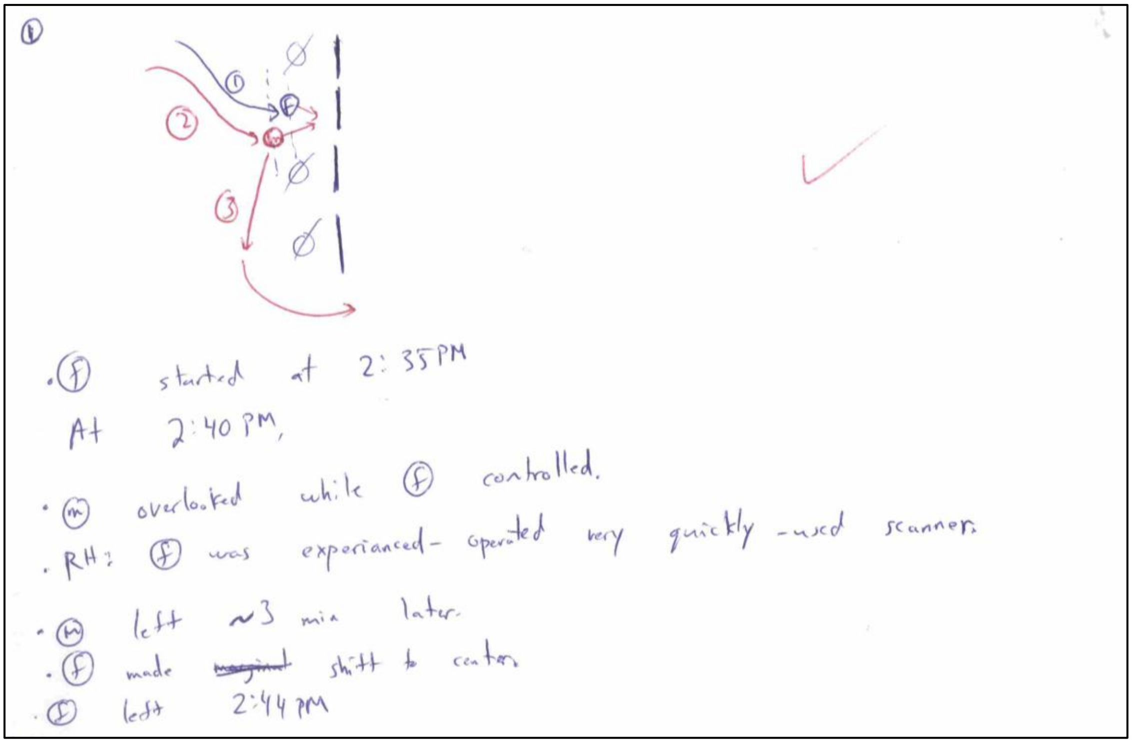
**Appendix A.1**: Sketch of two concurrent sessions at CINEMA.




**Appendix A.2**: Sketch of two concurrent sessions at MALL.



**Appendix A.3**: Sketch of a single session at PHOTO with notes.

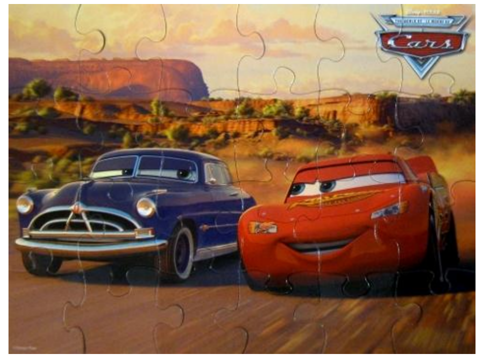


# Appendix B
# Control Study Puzzles

**Appendix B.1:** The five puzzles used in the Control Study. The letters correspond to those found in Figure 4.2.

**A.**

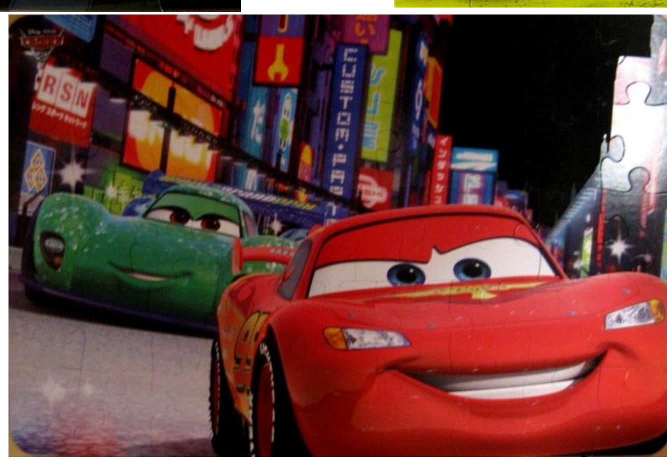

**B.**




**C.**


**D.**

**E.**



# Appendix C

# Control Study Participant Feedback

**Group Behaviours around Public Displays – Post-Session Questionnaire**

Your responses to the questions below will help us gauge the overall sentiment behind the study.

Please be advised that all responses **will be kept anonymous**.

Please circle the best response for each question below:

| | Strongly **Disagree** | Disagree | Neutral | Agree | Strongly **Agree** |
|---|---|---|---|---|---|
| I felt engaged by the task by solving it on a vertical display | 1 | 2 | 3 | 4 | 5 |
| Sharing the workspace did **not** bother me | 1 | 2 | 3 | 4 | 5 |
| I felt fatigued at some points in the session | 1 | 2 | 3 | 4 | 5 |

Please provide short answers to the following questions, if applicable:

1. For every puzzle, all the pieces were jumbled just below the static images and you either assembled the puzzle(s) off to the side or at the bottom. Do you think you would you have preferred it if the pieces were initially elsewhere, for instance, at the bottom initially? *Feel free to try it out for yourself on the whiteboard before answering.*

2. Was there anything about the task that gave you difficulty? If so, what?

3. Additional Comments (Optional).
   Feel free to jot down anything that made the experience notably positive/negative.

# Publications from this Thesis

Material, ideas, figures, and tables from this thesis have appeared previously in the following peer-reviewed publications.

Azad, A., Ruiz, J., Vogel, D., Hancock, M., & Lank, E. Territoriality and Behaviour On and Around Large Vertical Publicly-Shared Displays. *DIS 2012* (accepted March 17, 2012).