UNIVERSITY COLLEGE LONDON

MEASURING SPATIAL AND TEMPORAL FEATURES OF PHYSICAL INTERACTION DYNAMICS IN THE WORKPLACE

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I, Irene Lopez de Vallejo, confirm that the work presented in this thesis is my own.

Where information has been derived from other sources, I confirm that this has been indicated in the thesis. Dissertation word count: 90.904. Abstract word count: 298.

"It is fun to have fun, but you have to know how"

The Cat in the Hat

To Paul.

Thank you.

Abstract

Human behavior unfolding through organisational life is a topic tackled from different disciplines, with emphasis on different aspects and with an overwhelming reliance on humans as observation instruments. Advances in pervasive technologies allow for the first time to capture and record location and time information behavior in real time, accurately, continuously and for multiparty events. This thesis concerns itself with the examination of the question: can these technologies provide insights into human behavior that current methods cannot? The way people use the buildings they work in, relate and physically interact with others, through time, is information that designers and managers make use of to create better buildings and better organisations. Current methods' depiction of these issues - fairly static, discrete and short term, mostly dyadic - pales in comparison with the potential offered by location and time technologies. Or does it?

Having found an organisation, where fifty-one workers each carried a tag sending out location and time information to one such system for six weeks, two parallel studies were conducted. One using current manual and other methods and the other the automated method developed in this thesis, both aiming to understand spatial and temporal characteristics of interpersonal behavior in the workplace. This new method is based on the concepts and measures of personal space and interaction distance that are used to define the mathematical boundaries of the behaviors subject of study, interaction and solo events. Outcome information from both methods is used to test hypotheses on some aspects of the spatial and temporal nature of knowledge work affected by interpersonal dynamics. This thesis proves that the data obtained through the technology can be converted in rich information on some aspects of workplace interaction dynamics offering unprecedented insights for designers and managers to produce better buildings and better organisations.

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I started this thesis in January 2004. I finish it a husband, a daughter, a close family death, two jobs and 5 and a half years later. This has been a tremendous journey academically and personally. I set out to know everything about location technologies and buildings and, having learned a fair bit about both, I mainly have got to know myself best. The list of people that have contributed – either helping or hindering – to this thesis is very long. Many friends, family, colleagues and institutions have supported me through the ordeal. Special thanks go to the School of Graduate Studies, The Bartlett, for awarding me a departmental grant to cover my fees between 2006 and 2008 and to Debbie Williams, for reading and commenting on the text. My family in Spain deserves special mention for keeping me down to earth all this time.

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Chapter One:
Introduction – Goals of the Study

Abstract

This introductory chapter puts the main research question "how can location tracking technologies contribute to the understanding of face-to-face interaction in the workplace?" in context, initiating a discussion around a set of key concepts, technologies and methods (informal face-to-face interaction, knowledge gathering, transfer and creation, location technologies and location data, manual versus automated methods to study interaction) used throughout the thesis. Two main topics are briefly presented: firstly, the importance of informal face-to-face interaction in the efficacy of the communication process in organisations and the links that previous research has made between this type of interaction and innovation and knowledge transfer; secondly, the function that location tracking technology plays in the dissertation as a new tool to study the phenomenon of interaction in buildings. This chapter ends with a brief introduction to the narrative and structure of the thesis, chapter by chapter.

1.1 Introduction

Physical interaction dynamics are considered key to the organisational knowledge and innovation processes. However, understanding how people interact with one another in the built environment through time remains largely untested by empirical verification. Partially successful attempts have been made from different disciplines - architecture, management, environmental psychology and sociology to name but a few, to understand some of the spatial and temporal aspects of interpersonal dynamics in organisations and their buildings[1]. These attempts have been limited firstly by choosing one approach over the others, and secondly, by the nature of available tools and methods that produce information that is deficient to cover these aspects – space and time - longitudinally and comprehensively. From the perspective of building design, current approaches to the study of interaction provide only high level and general indications of how occupiers use buildings and fail to provide rich and longitudinal behavioural information that can further inform future design decisions. From a managerial perspective current approaches fail to provide rich and meaningful data that enables the organisation to use human resources and building together for maximum efficiency, particularly in terms of defining appropriate staff adjacencies and behavioural and work protocols through time.

Today, some indoor location tracking technologies can provide very precise position and time data, which are potentially the basis for highly granular information of interaction patterns. What these systems do not yet provide are the tools to transform raw location data into meaningful and manageable interaction dynamics information[2].

This dissertation aims to transform raw location data into meaningful information and use it to test and refine or challenge traditional hypotheses on the effects of certain spatial and temporal dimensions on interaction patterns. The significance of this research is its development of a method that enables the manipulation of the raw location dataset and its transformation into information relevant to the design of workplaces, the management of people and the further development of indoor location technology. Measuring interaction is an extremely difficult and costly process today, both for organisations and designers who need to gather information on human behaviour to proceed with the design of work structures and policies, and offices. Not having this information is in detriment of the success of all those designs and the availability of limited information results in partial pictures of the existing interaction dynamics. If the organisation, if the architect, can not measure interaction, and cannot do it in real time and where it really happens, it is not creating the best management and design strategies, and

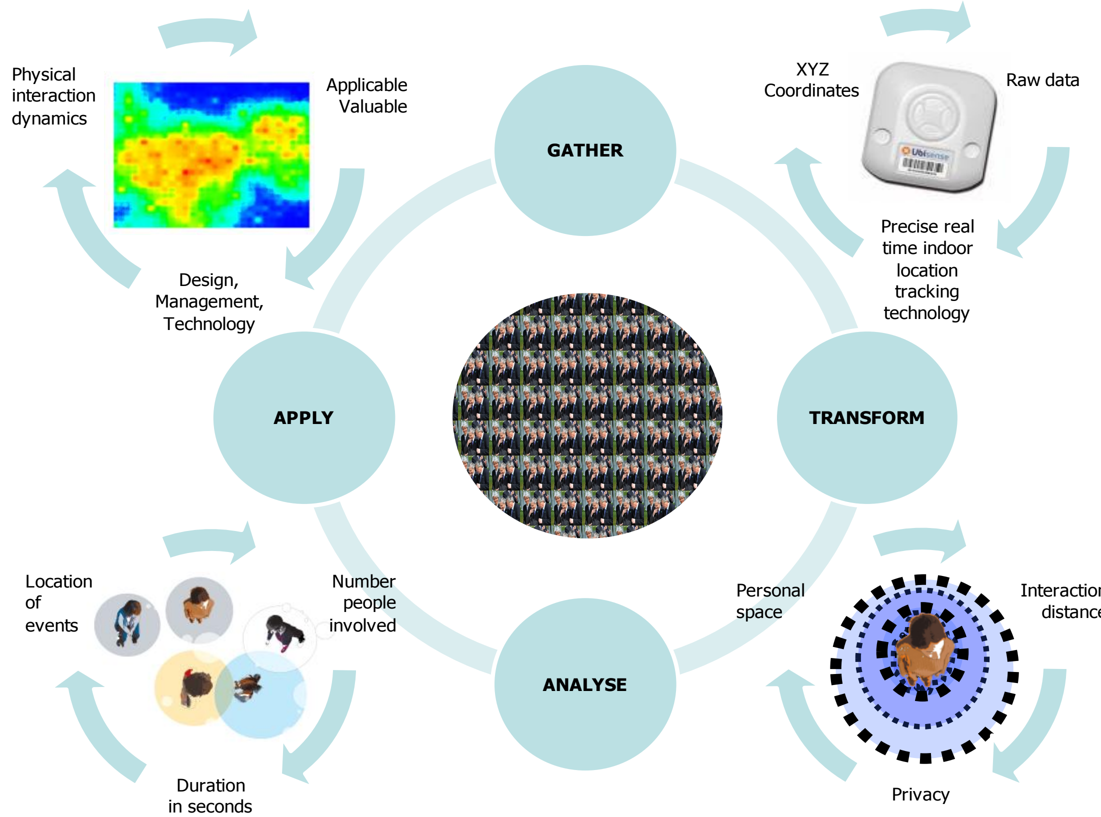


Figure 1.1 The Methodological Cycle of the Thesis: From raw location data to relevant interaction information.

therefore the best buildings and the best organisations.

1.2 Research Question

The central research question behind this study is '*how can location tracking technologies contribute to the understanding of face-to-face interaction in the workplace*[3]?' This section explains the decision to focus on face-to-face interaction and why this thesis uses location tracking technologies to investigate this phenomenon[4]. The focus is on face-to-face rather than virtual interaction firstly because face-to-face interaction is still the dominant form of interaction in most workplaces, and secondly, its study poses specific spatial and temporal problems that differ from understanding technologically mediated interaction. When interaction is mediated through a technology, it generally leaves a 'trace' that can be used to reconstruct patterns of interaction (e-mail logs, telephone logs, web site logs, etc). In the absence of technology, face-to-face interaction does not usually leave such measurable traces and its study is limited to observations and self assessments performed by individuals. The type of face-to-face interaction focused on by the thesis is informal rather than formal. Informal interaction can be defined in terms of its ad-hoc or unplanned nature and this class of interaction is the dominant form within many organisations (Kraut et al., 1990; Whittaker et al.,1994). See Chapter 2 for a discussion on the importance of interaction for organisations.

Understanding the spatial-temporal context of events is, arguably, the most fundamental and basic descriptor of daily life (Goffman, 1983). Location tracking technologies provide spatial and temporal data with varying degrees of accuracy – grain size of the position information - and precision – how often that accuracy can be expected to be obtained, usually expressed in a percentage (Hightower & Borriello 2001: 59). Today some indoor positioning systems can provide very fine grain information (Ibid. 61) providing data in a quantity and quality over long periods of time that no combination of manual methods can obtain. The location tracking data this research is based on was obtained from the deployment in a real environment, an office, of the most accurate and precise commercial real-time location solution available at the time, the Ubisense system (http://www.ubisense.net). This system, based on Ultra Wide Band (UWB) technology has an accuracy of up to 15 cm, precision of 95%, and multiple updates of location every second (Steggles & Gschwind 2005: 3). See Chapters 4 and 6 for further details of the technology and its deployment.

1.3 Key concepts

As stated previously, the focus of this research is informal face-to-face interaction dynamics and their spatial and temporal characteristics, and having outlined a justification of the use of location tracking technologies, a brief introduction to the key concepts that sustain this research seems appropriate. This dissertation dedicates Chapter 3 to identify the pre-conditions for interaction – physical distance, a place and a time (Goffman, 1983), and reviews previous research focused on these issues. Hall's theory of Proxemics (1959, 1963, 1966, 1968) has been used to infer physical presence from the highly granular location data. To deduce these interactions around each tag (and therefore around each individual), an area of 0.75 metres radius is defined, which marks the personal distance each individual maintains with others in interpersonal encounters. Interactions are inferred when these personal areas overlap for a predefined period. When those areas are not trespassed the individual is supposed to be on his own, potentially engaged in solo activities. In this way location tracking data are used to infer the occurrence of face-to-face interactions between people, their precise location and the amount of time spent interacting and engaging in solo events.

Chapter 3 shows how current methods obtain data based on observations, self-reports and surveys which do not provide comprehensive and long term datasets. In contrast, the method proposed in this thesis to study informal face-to-face interactions in the workplace using location tracking data is based on the analysis of the spatial and temporal relationships between the potential millions of data points obtained. It is not so much the highly accurate and rich information obtained through the technology, as the structures and arguments that can be built upon it that is the focus of this research. Current commercial location tracking solutions do not provide the tools that allow performance of the analysis. *This piece of research develops some tools that allow us to capture and segment these relationships.*

The analysis of data from location tracking systems provides an opportunity to understand human behaviour in ways that have been, until now, impossible to achieve. Instead of relying on observations recorded by humans, limited in the number of observations that can be recorded within an given interval and in terms of the precision with which particular positions can be recorded, location tracking technologies can provide highly granular position and time data. In addition, while the cost of setting up these systems is high at present, once in place the system can continue to gather data for as long as is required. It is simply not possible to use human observers to gather this type of data over long time scales. The alternative approach to human observations or, in some cases, complimentary approach has been to use subjects' self-reported perceptions of interactions patterns through surveys. This approach also has clear limitations with respect to the data gathered due to the well documented problem of the variance between subjects reporting of their behaviour and their actual observed behaviour. See Chapters 3 and 4 for a review of current methods and issues of reliability of systematic observation methods.

The potential that location tracking technologies have to provide a long time series of highly accurate data on actual patterns of behaviour could significantly change current approaches to understanding that behaviour. However, it has to be demonstrated that the data gathered can contribute to our knowledge of human behaviour. The key research contribution of this thesis is to demonstrate that this data can be structured and analysed in such a way to add to this knowledge[5].

Location tracking technologies are currently rarely deployed in office environments. Nonetheless, in the future, the need for organisations to understand how their buildings and staff perform, in a context where the workforce is evolving towards increased flexibility and mobility in their working ways, coupled with the trend towards total connectivity of communication devices, will arguably be a powerful driver for the introduction of different location based technologies, systems and solutions in the workplace. From a managerial perspective, knowing the specifics of staff interaction rhythms would enable a company to potentially tailor work processes and possibly achieve a more efficient organisation. From a spatial perspective, architects and designers will have to be ready not only to have an informed understanding of those systems, but mainly of how to use the information gathered on building and occupier use to improve the solutions provided to clients. Specifically, a better understanding of the fine grain of interaction would make it possible to link activities to workplace design in a much more accurate and dynamic mode than is possible today with current methods; and as a consequence, devise better environments.

1.4 Research Hypotheses

Having introduced the research question, the role of location tracking data in answering that question and the key concepts this thesis deals with, it is necessary to present the premises that drive the tool development. The study is divided into two main areas: the development of a new automated method to investigate physical interaction dynamics, and its testing and validating.

The aim of the method is firstly to establish an adequate format and size of the interaction information that will allow the segmentation, detection, representation, and visualisation of the flow of face-to-face interaction and solo events inside buildings, in order to, secondly, produce useful information that managers and designers can incorporate in their decision making processes. The tool development and testing need to be driven in the context of concrete hypotheses.

These are of two types. Firstly, concepts and measures of personal space, interaction distance and privacy regulation, including the regulation of interpersonal boundaries, are used to define the mathematical boundaries of interaction and solo events. These conform to what has been called in this thesis the automated coding scheme (see Box 1). And here lies the thesis novelty. Afterwards, MATLAB is used to manipulate the raw dataset in order to obtain information about interaction and non interaction events, their number, volume of people involved, precise location and temporal aspects of the events. With that information further statistical analysis is done and made meaningful through interpretation.

Box 1. Automated coding scheme

- **Interaction Radius** – Interaction distance is defined as a bubble of 2.5 feet (0.75 m) radius around the individual: an area that marks the extension of the close phase of the individual personal distance.
- **Solo** - Solo behaviour occurs when one person's 0.75 m bubble is not overlapped by another person's for at least 10 seconds.
- **Interaction** - Face-to-face interaction occurs when one person's personal space boundary is overlapped by another for at least 15 seconds.

Figure 1.2 Behavioral codes used to develop the automated method.

Once it has been made possible to count events of interaction and non interaction, and attach a precise location and time to each of them, some of the most elusive aspects of spatial and temporal aspect of interpersonal dynamics, and their combinations, can be explored in detail for the first time. Sequences, duration, pace and rhythm of interpersonal dynamics can be studied in a way that provides pervasive coverage of those dynamics and their evolution through time together with their specific location. These aspects are reflected in specific hypotheses based on literature review findings reported in Chapter 3 (see Box 2). It is noteworthy that these research findings lack representativeness due to the small number of studies tackling temporal and spatial issues of interpersonal dynamics and the small samples employed. Further refinement of these hypotheses is expected to be obtained using the new location tracking dataset (see Chapter 4 for further details).

But the investigation is not limited to the use of the location tracking dataset. Tools that are currently employed to understand aspects of face-to-face interaction in buildings and their organisations are also utilised. The same hypotheses are used; results are reported on in Chapter 7 and Chapter 8, and a comparison of the results of using both an automated method and manual methods of observation will be presented in Chapter 9.

Box 2. Hypotheses

H1 Knowledge workers spend variable portions of their working days interacting face-to-face and in solitary activities.

H2 Knowledge workers spend an average of 3 minutes in informal face-to-face interactions, most of them lasting less than 38 seconds. Solo events duration varies between 4 minutes and an hour.

H3 Knowledge workers spend more time interacting face-to-face the higher the number of individuals involved.

H4 Knowledge workers spend more time interacting face-to-face depending on the location of the interaction.

H5 Knowledge workers spend more time in solitary events depending on type of location.

Figure 1.3 Hypotheses testing automated method potential.

1.5 Methodology

The primary research strategy chosen is the case study. This is an empirical inquiry that investigates a contemporary phenomenon - face-to-face interaction - within its real-life context - an office environment. A"single unit design" case study is used, where a critical case is chosen to challenge existing theory. Limitations of this approach are discussed in Chapter 4 (Yin, 2003).

The subjects of the study are office workers, both those wearing tags and being tracked, as well as those experiencing the deployment of the location tracking system. The data for the case study comes from different sources of evidence: the technology, observations, survey and interviews. The technology is the key source of data to test and refine the hypotheses. The rest of the information is used to draw a context for the deployment of the technology and to compare the results obtained with the new method and with the manual methods. Manual or non-automated observations of space use are used to develop an understanding of the office environment under study, specifically of the variety of different spaces available to support different activities and of the way that these spaces are utilised by staff.

Box 3. Propositions

P1 The experience of the surveillance will manifest itself in negative attitudes toward the technology deployment.

P2 Participants in the deployment will tend to mystify the scope and capabilities of the technology.

P3 Wearing the tag will raise complaints that will diminish through time.

Figure 1.4 Propositions

These observations provide the researcher with a rich context within which data from the location tracking system can be situated. The research also uses interviews with staff to explore the more qualitative aspects of the use of the technology. The practical potential for increasing understanding of interaction in the workplace through the analysis of location tracking data depends critically on the acceptance by staff of these location tracking technologies. Interviews are used to detect staff attitudes towards the technology, their understanding of the technology and how their attitudes towards it changed through time. The propositions leading this part of the case study are summarised in Box 3.

1.6 Audience for research

This thesis aims to develop some tools that will provide managers, architects and designers with rich,spatial, temporal, multiparty, continous, longitudinal – information to create better working environments. Along the way, it will also provide insight on the use of the technology and, most importantly, on human behaviour in buildings.

This piece of research develops the tools needed to transform highly granular raw location data into manageable information that allows for the capture and representation of informal face-to-face interaction relationships.

1.7 Outline of proposed research

The thesis unfolds as follows:

Chapter 2 - Interaction in organisations, puts in context the phenomenon of informal face-to-face interaction in organisations from a management and design perspective. The chapter opens by arguing that organisations are complex entities whose study is covered by many fields working in parallel. Findings are rarely transferred between these fields and, in consequence, the study of interaction in organisations appears fragmented and at times contradictory. This thesis aims to develop a new method for studying interaction in office buildings. For this reason it is important to understand why interaction is important, what type of interaction is more relevant, and what benefits it brings for companies. In addition, it examines the strategies, both organisational and design related, that firms put in place to encourage these dynamics, and what the potential drawbacks are that the implementations of such policies might provoke. A discussion of the link between interaction, knowledge and innovation closes the section. This chapter concludes that informal face-to-face interaction is a process that cannot be manufactured. The conditions for it need to be created, rather than planned. The next question is: what are those conditions?

Chapter 3 – Preconditions and Measurements for Face-to-Face interaction, aims to describe face-to-face interaction, identify the conditions that enable it and identify a set of criteria for its measurement, focusing on the workplace context. The section opens with an overview of Goffman's research on face-to-face interaction which provides a conceptual map for the phenomenon and identifies its key enabling conditions. The identification of some dimensions of these three preconditions through literature review aims to define a set of criteria that will become the building blocks of a new method to study face-to-face interaction in organisations. The examination of research also reveals currently understudied spatial and temporal dimensions of face-to-face interaction that can contribute to a better understanding of work dynamics and improve work structures and office designs. The chapter closes by recognising the need to enhance current methods to study physical interaction in organisations in order to provide a holistic - real-time, continuous, multiparty and longitudinal – picture of its dynamics. Could new technologies possibly help to bridge this gap and articulate such methodology?

Chapter 4 – Methodology, focuses on describing the method created with the purpose of finding new ways to segment, detect, represent, and make visible the flow of informal face-to-face interactions inside buildings. Building on the measurements identified in Chapter 3, this section presents a novel methodological development that focuses on the study of interaction dynamics in the workplace. Using highly accurate location tracking data, the thesis attempts to test and refine well established hypotheses regarding the effects of interpersonal distance and aspects of time and space on informal face-to-face interaction patterns. Observations and interviews are conducted to contextualize the location data. Geographical Information techniques and software (MapInfo), and Computer Assisted Qualitative Data Analysis (CAQDAS) are used, respectively, to visualise and investigate the results. New tools to study face-to-face interaction are the main outputs of this thesis, together with design, management and technology recommendations. Limitations to the approach and contribution to research are discussed.

Chapter 5 – Case study site, offers specific detail about the organisation and the environment where the study was conducted. The organisational context, the technology deployment, access to the site and the strategy to gather data are all described. This section introduces the different nature of the datasets used in the thesis, the limitations faced in practice, and gives an overview on participation and ethical issues.

Chapter 6 – Workers' attitudes towards the technology deployment, presents in-depth insights into the most intangible aspects of the technology deployment that lurk underneath the counting of activities and their repetition and beyond perceived and reported behaviour. Starting with a discussion on the physical aspects of the deployment and the technical, spatial and social challenges posed to both the organisation and the technology developer, this chapter narrates the participants' perceptions and attitudes towards the location system, from their point of view. Specific issues of communication, time, privacy, and culture emerge and a discussion of potential further research paths opened by this part of the study displayed. The interviews conducted are enhanced by participant observation which allows a complex socio spatial and technical situation to be portrayed in detail.

Chapter 7 – Measuring physical interaction spatio-temporal features with manual and other methods, presents aggregated findings regarding the use of space and the different activities observed through time as well as the results of a questionnaire where issues of work style and perceived interaction were explored. Descriptive statistics, tables, graphs, and maps – including VGA (Visual Graph Analysis), are used to draw a picture of existing interaction dynamics and of the physical and organisational circumstances where the location tracking data are collected.

Chapter 8 – Automated observational measurement of interpersonal spatio-temporal dynamics in the workplace. The chapter starts by describing the basic statistics of the manipulated raw location dataset. It continues with a number of statistical and spatial analyses of the dataset that will allow us to test and refine the hypotheses. This part of the thesis aims to categorise face-to-face interaction by the variety of duration, group size, number and location in the office.

Chapter 9 – Discussion, summarises the differences in approach pointing at the deficiencies of current methods and how this new technique has the potential to bridge them. The main aim of this section is to illustrate how far into measuring the spatio-temporal interaction variables set up in chapter 3 we have gone, to compare type of findings (qualitative vs quantitative), type of data (automated vs manual) obtained and the value of the different datasets (cost/benefit analysis)..

Chapter 10 – Conclusions, takes the theoretical and methodological conclusions of the thesis and discusses their implications in a wider academic and organisational context presenting a statement of future research and potential practical consultancy directions that could arise from the body of work forming this thesis.

Key Questions

- Is interaction a strategic issue for organisations?
- What type of interaction is most beneficial from a business perspective?
- What are the basic conditions for face-to-face interaction to occur?
- What is the potential role of location tracking technologies in understanding social, spatial and temporal dynamics in an organisation?
- What are the attitudes of workers towards the potential deployment of location tracking technology in the workplace?
- What are the benefits this new method has over currently used ones?
- What are the applications the new dataset provides in the fields of design and management of organisations?

Notes

1 "The core purpose behind the creation of buildings, [is], to accommodate a business or other organisation and enable it to meet its core purpose" (RICS 2008:33).

2 While the deployment of location tracking technology in office environments is extremely rare at this point in time, creating significant problems in terms of the availability of case studies, its use is likely to become more common in the near future. Sadly, current initiatives using these technologies focus on surveillance of population, which does not contribute to its social acceptance. One such example is the "Golden Shield" project developed by the government of China, which is using the latest people tracking technology to develop a surveillance shield to identify and counteract social dissent before it happens (Walton 2001).

3 Workplace is understood throughout the thesis as the physical work setting where work is done primarily through workers daily face-to-face interactions. "The workplace is the physical embodimenty of the office despite the trend towards mobile, home and other form of flexible working" (RICS 2008:13)

4 The very preliminary ideas that motivated the author to start this thesis are outlined in preovious publications delaing with pervasive technologies and human and social factors (Lopez de Vallejo, 2003, 2004, 2005).

5 Please note that this process transforms millions of location-time data points into thousands of relatively manageable, more focused information that needs to be further manipulated and compared with other sources to make practical use of it. To illustrate this point the thesis' case study comprises 51 individuals wearing tags that update their location in the office environment every second. 1 day of data, for 51 tags, for a working day of 8 hours, throws potentially – provided that the system works and that all individuals wear the tag - 1.468.800 location points (format Cartesian Coordinates x,y,z data points). Excel 2003 has a capacity of 65.000 rows on a worksheet and Excel 2007 has over a million rows. The point is that without the MATLAB program used in this thesis and the coding scheme to lead the manipulation of the raw data, the initial outcome dataset is extremely difficult to manage. See Chapter 4 for a description of the methodology proposed.

Chapter Two:
Interaction in organisations

Abstract

The objective of this chapter is to put in context the phenomenon of informal face-to-face interaction in organisations from a management and design perspective. The section opens by arguing that organisations are complex entities whose study is covered by many fields working in parallel. Findings are rarely transferred between these fields and, in consequence, the study of interaction in these entities appears fragmented and at times contradictory. This thesis aims to develop a new method for studying interaction in office buildings. For this reason it is important to understand why interaction is important, what type of interaction is most relevant, and what benefits it brings for companies. In addition, it examines the strategies, both organisational and design related, that firms put in place to encourage these dynamics, and what the potential drawbacks are that the implementations of such policies might provoke. A discussion of the link between interaction, knowledge and innovation closes the section. This chapter concludes that informal face-to-face interaction is a process that can be nurtured but not manufactured. The conditions for it need to be created, rather than planned for. The next question is: what are those conditions?

2.1 Interaction: a context

When it comes to understanding the role that the phenomenon of face-to-face interaction plays in today's company, organisational researchers and practitioners face theoretical and methodological challenges alike. Whereas the lack of a sound theory of interaction in organisations makes its framing difficult, current methods fail to provide a picture that comprehends the highly complex and flowing nature of interaction dynamics in the workplace[1]. Together these two issues present the main challenges towards the development of effective and efficient management and design strategies for interaction, and are the cause of preventing interaction from its recognition as a "substantive domain in its own right" (Goffman, 1983: 2).

Research into organisations is complex and multifaceted (Hatch, 1997: 7). It encompasses the study of the organisation as a cultural, social, physical and technological entity embedded in and contributing to an environment (Ibid.: 15). The study of these broad areas has been covered by the fields of strategic management, organisational theory, industrial sociology, organisational behaviour, organisational communication, environmental psychology and workplace design among others. These areas often overlap in their coverage of the subject matter. More often than not, research in one area does not transfer into the others. Specific topics are covered from a single perspective and the result is an isolated picture of a complex phenomenon. This is a disadvantage when it comes to understanding the multiple dynamics taking place in the context of the organisation (Ibid.: 8).

Take interaction as an example. All the above mentioned fields state its importance to today's organisation, but none of them share a common theoretical framework to understand it, an established set of methods to study and measure its dynamics, or a group of recognised organisational and design strategies to encourage the creation of interaction in an organisation. Noticeably, those fields do not share theory, methods or strategies, although some areas borrow from others ideas and methods to apply in the study of organisations from their own perspective. What is more, these fields also do not have a unified theoretical and methodological framework for understanding the importance of interaction for today's organisation.

In the context of this thesis, whose main aim is to develop a new method to study interaction in office buildings, a review of existing theory and methods that focus on interaction in organisations from multiple perspectives, is essential for the contextualisation of the research. There is a need to synthesise different views and use this knowledge to push the domain of interaction forward.

This method will also offer an unprecedented real time, continuous, multiparty and potentially longitudinal[2] understanding of the nature of interaction patterns in organisations. Now, the questions are, why would firms want to know more about face-to-face encounters? And, what are the potential benefits of having richer information about interaction in buildings for those organisations?

To answer these questions, this section opens the discussion by introducing the role of interaction in today's organisation, arguing that interaction is key for the gathering, creation and transfer of knowledge in organisations. Physical interaction, and in particular informal face-to-face interaction, is the most beneficial type of activity when it comes to knowledge creation. The key benefits of interaction for knowledge-intensive companies are described, as well as the diverse organisational and design policies and strategies that firms put into place to encourage interaction. A discussion of the drawbacks of interaction and the – often ignored - importance of spending time alone follows. Next, a brief review of literature regarding the link between interaction, knowledge and innovation is presented. The section ends with some conclusions on the role of interaction in today's firm that will allow to progress towards the exploration and identification of the conditions and circumstances that enable face-to-face interaction in chapter 3.

2.2 The role of interaction in today's organisations

Literature suggests that organisations that place an emphasis on interaction are knowledge intensive firms, driven by the assumption that knowledge is their most valuable resource and that new knowledge is created through the recombination and exchange of existing knowledge embedded in the minds of individuals (Nonaka, 1994; Nonaka and Takeuchi, 1995).

Knowledge-intensive companies are "firms where most work is said to be of an intellectual nature and where well-educated, qualified employees form the major part of the work force. The company claims to produce qualified products and/or services." (Alvesson, 2001: 863; Starbuck, 1992). Typical examples are "law, accounting, architectural firms, management, engineering and computing companies, advertising agencies, R and D (Research and Development) centres, (and) IT (Information Technology) companies" (Alvesson 2001: 863).

Some authors call attention to the ambiguity of the term knowledge-intensive organisation. But since there are differences between professional service and high-tech companies on one side, and more routinised service and industry companies on the other, it makes sense to talk broadly of knowledge intensive companies "as a vague but meaningful category" (Alvesson, 2001: 864). Alvesson argues further that it is perhaps the "claim to knowledge-intensiveness" which most distinguishes this type of organisation, that is, putting the emphasis on knowledge to legitimise what knowledge organisations and knowledge workers do (Ibid.: 864). But not all organisations are knowledge-intensive nor do all claim to be knowledge-intensive. Therefore, not all organisations will place emphasis on the importance of the individual as a recipient/source of knowledge and hence in interaction as a mechanism of its creation. This thesis focuses on those organisations that do and its findings are relevant specifically to them.

In knowledge-intensive firms human capital dominates and knowledge has more importance than capital or labour (Starbuck, 1992). Employee knowledge is a valuable resource and firms have come to understand that they require a strategic approach to corporate knowledge if they are to succeed in today's and tomorrow's economies. Davenport and Prusak affirm that "…the management community has come to realize that what an organization and its employees *know* is at the heart of how the organization functions" (Davenport and Prusak, 1998: introduction X).

The management of interaction processes is seen as the cornerstone in the process of carrying out knowledge-intensive work (Grant, 1996a; Nonaka, 1994; Nonaka and Takeuchi, 1995; Spender, 1996; Alvesson, 1995, 2001). Alvesson (1992) refers to a study he conducted in a computer consultancy where, for the consultants interviewed "(the) technical aspects were less crucial for the success of projects than the social relations within project groups and in relationship to clients: getting along, clarifying expectations and obtaining acceptance for solutions were critical" (Ibid.: 195). In the same study, he also points out the importance that the computer consultants gave to "the management and manipulation of social relations and belonging to the right association or informal network of knowledge-intensive players" to compensate for the "intangible, ambiguous character of the service being offered. Social relations and personal knowledge sometimes matter as much as or more than market transactions and quality/price based competition" (Alvesson, 2001). In contrast, Nonaka stresses the role of the organisation in managing those relations. He argues that individuals, and specifically "interaction between individuals" (Nonaka, 1994: 15, 17, 18, 19, 22), are key to the development of new knowledge, although it is organisations that play a critical role in articulating and amplifying it. At the beginning, informal interactions in the form of "informal community of social interaction" and of "informal groups" (Nonaka, 1994: 17) is the tool that provides a medium for sharing information and ideas. These interactions can spread throughout the firm, i.e. involving more individuals, and beyond it i.e. involving clients and suppliers, and the organisation needs to link the informal contributions to its formal structure.

Knowledge is not just another resource alongside the traditional factors of production. Knowledge today is the new basis of competition and the only meaningful resource for organisations (Drucker, 1993). Knowledge resides in the minds of individuals and "knowledge is created through interactions" (Nonaka and Toyama, 2007: 24), for, Nonaka points out, an individual's contributions "remain personal unless they are articulated and amplified through social interaction" (Nonaka, 1994: 22).

All evidence presented suggests that to create new knowledge and transfer existing knowledge individuals need to interact. Interaction is therefore a key issue for today's firms. But it is necessary to point out that most of this evidence can be considered conceptual pieces lacking a thorough scientific approach to the role of interaction as essential to the knowledge process. Views and beliefs on the importance of interaction stem from high-level consultancy and research conducted with other aims in mind. Interaction appears to be a key enabling mechanism of higher level processes, its importance highlighted but its rigorous study left aside in the pursuit of other subject matters.

2.3 A most beneficial type of interaction

Nonaka affirms that all knowledge generation, at its most basic level, implies social exchange in the form of some type of interaction. It does not have to be through language, it can be done through "observation, imitation and practice" (Nonaka, 1994: 18).

Webber states that face-to-face interactions seem to be "the most important form of work. Conversations are the way knowledge workers discover what they know, share it with their colleagues and in the process create new knowledge for the organisation" (Webber, 1993: 28). Conversations facilitate communication among workers (Ichijo, 2007: 87) and Cohen reports that "face-to-face relationships are still the only truly effective way to transfer tacit knowledge" (Cohen, 1998: 37).

Davenport and Prusak go further, affirming that "Spontaneous, unstructured knowledge transfer is vital to a firm's success" (1998: 89). These informal, unstructured transfers of knowledge, these so called "water cooler moments" - because they tend to happen around informal meeting spaces such as the water cooler or the vending machine - open the door to serendipity and to the potential to generate new ideas or solve old problems in unexpected ways (Ibid.: 91; Purser et al., 1992; Fayard and Weeks, 2007). Informal face-to-face interactions are casual, unstructured encounters "that which remains when rules and hierarchies, as ways of coordinating activities, are eliminated" (Kraut et al., 1990: 5). These conversations "take place at the time, with the participants, and about the topics at hand. None of these characteristics - timing, participants, or agenda - is scheduled in advance" (Ibid.: 5).

Ruggles, quoting research conducted by The Institute for Research on Learning, says "it is the informal, socially constructed communities of practice that form within organizations that are the true mechanisms through which people learn and through which work gets done" (Ruggles, 1998: 85). Informal knowledge-transfer and learning depend on informal face-to-face interaction to occur.

Other studies have highlighted the importance of face-to-face interaction accounting for its incidence and quantity. Kraut and his collaborators argue that, "if a behaviour pattern occurs frequently enough, it is likely to be important for a species or group"(Kraut et al., 1990: 13), and informal interaction is the most frequent activity in workplaces "accounting for over 85% of the interactions"(Ibid.: 19). Whittaker and colleagues in a later study proved that informal physical interaction activities account for up to 31% of the total work time (Whittaker et al., 1994: 133).

Davenport and Prusak identify two main reasons that can potentially hinder interaction and, therefore, informal knowledge-transfer in the workplace. Firstly, the move to "virtual offices", while providing other benefits such as flexibility and more time with customers, also threatens the transfer of knowledge through personal conversations. Secondly, traditional managerial attitudes to work – "Stop talking and get to work!" (Webber, 1993: 28) - threaten informal interactions that happen in places like the water cooler or the company café (Davenport and Prusak, 1998: 91).

Face-to-face interaction and, specifically, informal face-to-face interaction is the most important type of social encounter happening in the workplace. It is a vital mechanism for informal knowledge-transfer, the generation of ideas, learning and to get work done. Informal face-to-face interaction is also the most frequent activity in today's workplaces. Literature suggests that it is a process that needs to be nurtured from within the organisation: the firm needs to be strategically oriented towards knowledge-transfer and its generation and keen to set up processes that encourage it. This is a phenomenon that is vital to the firm's success and recurrent in its day-to-day routines. The next logical question to ask is what are the specific benefits that informal face-to-face interaction brings into organisations?

2.4 Key benefits of informal face-to-face interaction for organisations

Informal face-to-face interaction benefits organisation processes in that it builds trust relationships that keep the flow of ideas moving and are highly valued by workers.

Informal interaction builds trust. "Personal contact and trust are intimately related" (Davenport and Prusak, 1998: 35). There is no substitute for direct face-to-face contact when it comes to building relationships and trust inside the firm (Ibid.: 100). Trust "is a device for stabilizing interaction" (Giddens, 1988: 276). Trust is essential to firms because it "creates the invisible ties that bind people and companies together and converts mere transactions into personal relationships" (Webber, 1993: 41). Trust and respect keep the flow of ideas open in an organisation. This is particularly important for the sharing of high value or high-risk information (Hall, 2001: 16).

Informal interaction stimulates the flow of ideas inside the firm. People meeting together stimulate the exchange of ideas and stimulate creative action (Buchel, 2007: 45) inside the organisation. The benefit of stimulating the flow of ideas has three aspects to it. Firstly, companies abound with ideas that are not adopted because of organisational barriers, and to encourage informal interaction can help to overcome the barriers and get those ideas to flow (Nurmi, 1998). Secondly, a healthy flow of ideas facilitates knowledge-gathering and exchanges of information inside the firm (Haas, 2006; Dahl and Pedersen, 2004; Ichijo, 2007), learning (Ruggles, 1998: 85) and the "sorting out of useful ideas out of the general chatter of a community" (Wu et al., 2004). Finally, the speed at which knowledge moves through an organisation, what Davenport and Prusak call "velocity", is a factor that affects the success and efficiency of knowledge transfer, (Davenport and Prusak, 1998: 102). Informal face-to-face interactions are "the key resource for competing in time" (Webber, 1993: 29).

Companies pick up subtle changes in the market, spread that awareness rapidly through the organisation and are better positioned than their competitors for a fast response. The flow of ideas stimulated by informal interaction helps overcome internal and external barriers to communication, facilitates knowledge movement and learning inside and outside the firm and allows for a faster response to market changes.

Informal interaction is highly valued by workers for social reasons. Informal face-to-face interaction is also particularly useful in supporting the social functions of groups such as team building and is highly valued in order to solve conflicts and get work done (Kraut et al., 1990). This can be partly explained because "organizations are usually less explicit in regulating social relationships than they are in regulating other aspects of work procedures" (Ibid.: 7). Knowledge workers perceive social relations within the organisation and in relation to clients, such as getting along or clarifying expectations, to be key to the process of carrying out knowledge-intensive work and more important in complex projects than the technical aspects for their success (Alvesson, 1992, 1995, 2001). People meeting together also develop relationships that, if beneficial for all sides, strengthen through time and these relationships are extremely valued by workers at a personal level. As Hargie and Tourish put it; "humans still prefer to interact with one another in person" (2004: 249). In very simple terms, we all like to work with people, and especially with people we like.

Specifically, when new ways of working are deployed – such as flexible working schemes – workers consistently report the value of interaction. Working in isolation is a major downside to these practices and interaction is perceived as necessary to maintain a good level of communication with colleagues, managers and clients alike (Puybaraud, 2007).

Informal face-to-face interaction is therefore a key issue for organisations from a strategic and a social point of view. Beneficial, informal, interaction dynamics are those that enable the flow of ideas and creativity that help to overcome organisational structural barriers, facilitates the circulation, gathering and exchange of knowledge and are highly desirable specifically in the complex and uncertain situations that develop in knowledge firms. Trust is built and consolidated through face-to-face encounters and engenders respect inside and outside the organisation, which in turn keeps the above mentioned flow of ideas open. Socially, this type of interaction is highly valued by staff who appreciate the intangible benefits of direct contact and relationship-building with colleagues and clients alike to get work done.

2.5 Organisational strategies to encourage informal face-to-face interaction

The previous points have argued for presenting face-to-face interaction in the workplace as a complex multifaceted phenomenon rooted in the operation of the complex institution which is the firm. This type of behaviour is a process valued by those organisations that perceive their human capital as key to the success of the business, and is recognised as an essential mechanism in the process of creating new or transferring existing knowledge. Informal face-to-face interactions lead to the building of trust, facilitate the flow of ideas and creativity in the organisation and are highly valued by knowledge workers in the accomplishment of knowledge work.

With the recognition of the importance of interaction in getting work done comes the recognition of the need to create processes, structures and environments that enable workers to interact both formally and informally. The focus of this section is on the strategies put in practice by organisations to encourage informal face-to-face interactions in the workplace. The ways described herein have been proposed and applied in firms with the aim of creating a context where the interactions are productive and useful for workers, clients and the company as a whole.

The motives that different organisations have for employing such strategies vary depending on their strategic orientation towards knowledge. They vary from the examination of the effects of interpersonal communication on market and technological learning (Moenaert and Caeldries, 1996: 296), to the achievement of a more even spread of information, improved coordination, group formation, improved organisational agility, innovation, reduced time to market, greater organisational efficiency (Rashid et al., 2006: 827) increase of speed to market, reduction of research and development costs and integration of different types of experience inside the company (Prusak and Weiss, 2007: 41). The ultimate objective of the strategies described is always to promote informal knowledge transfer that will help the firm articulating the process of actively developing the new knowledge needed to solve problems and therefore, to produce innovative solutions (see point 1.6 for a discussion on the link between interaction, knowledge and innovation). Face-to-face interaction is used explicitly as a mechanism to achieve the gathering, locating, transferring and creating of knowledge.

It is worth mentioning at this point that there are two views of the knowledge-based firm that influence organisations' strategies. One suggests that the organisation's primary role is knowledge application, with the firm being seen as "an institution for integrating knowledge" (Grant, 1996b: 109). The other argues for a view of the firm whose main aim is to create information and knowledge (Nonaka, 1994). The firm can be understood as "that particular mode of governance which fosters the interactions that lead to knowledge growth" (Spender, 1996: 49). The first view stresses the transfer of existing knowledge, whereas the second emphasises the creation of new knowledge. Both perspectives nevertheless, stress the role of individuals as recipients of knowledge and interaction as key to the process of creating new knowledge. The first view directs its attention to the "mechanisms through which organisational knowledge is created through the interactions of individuals" (Grant, 1996b: 113), in contrast to the second, which focuses on explaining the critical role firms play in articulating and amplifying knowledge created by individuals interactions (Nonaka, 1994). Some researchers point at the excessive emphasis placed on the individual as opposed to teams of individuals working together, and advocates the need to explore knowledge transfer and creation processes both singly and collectively (Hall, 2001: 1; Leonard and Sensiper, 1998: 115).

Trends in academia related to interaction behaviour in organisations - be it strategic management, social psychology, environmental psychology, sociology of work, workplace design or others - are paralleled by those in the management of day-to-day workplaces. After decades of rejection of the importance of the organisation's human assets to the business, pioneer senior managers started to adopt an employee-centred thinking around the 1960's. By the late 1980s and early 1990s, there was recognition that it was not so much the firm's tangible assets that mattered as the way they were being used and combined with individual and organisational knowledge (Spender and Grant, 1996: 6). These days, knowledge-intensive organisations face "…three simultaneous challenges: how to continuously innovate, operate with speed and agility in view of short product and service life cycles, and create an organization geared for flexibility to deal with unexpected changes" (Bahrami and Evans, 1997: 23). These challenges demand a work context – characterised in knowledge organisations by its "intensity, novelty and collaborative teamwork" (Ibid.: 23) – that balances the creation of the best possible physical environment that can reinforce the desired interaction patterns, an organisational structure flexible enough to cope with hectic work dynamics, and a technological infrastructure that facilitates distant communication and information exchange (Ibid.: 23).

The need to face these strategic management challenges led to the interest, on one hand, in new forms of organisation (Spender, 1996: 47) and on the other, in design as a strategic tool to support those emergent organisational forms (Vischer, 1996). Therefore, the strategies that firms have put into practice to encourage interactions have emphasised change either in the design of the organisation's structure, in the design of the physical environment of the organisation or on the technological infrastructure necessary to enable remote information exchange. Research that focuses on the study of physical interaction – such as this thesis[3] - deals only with the first two types of strategies.

Organisational theory and research tend to focus either on the management and alignment of the interaction processes affecting the gathering, creation and transferring of knowledge inside the firm or on proposing and testing design solutions using the building interior as the vehicle to encourage informal encounters. These studies tend to separate both areas for the sake of clarity, but ultimately all of them acknowledge the importance of the other aspect and in practice both aspects often intermingle in the strategies implemented by firms.

To bring this section to a close, it is worth mentioning that both organisational and design strategies to encourage interaction and informal exchanges of knowledge are thought of and implemented in the wider context of the firm where the final objective is not exclusively the increase in the number of encounters per se, but the shaping of the work context as a whole. Formal organisational structures may constrain or enhance the effectiveness of these strategies and extend well beyond them (Haas, 2006: 1181). Aspects of formal structure that may constrain or facilitate informal exchanges are: the extent to which the organisation rewards innovation, the formal distribution of power inside the organisation and the level of bureaucracy, amongst others (Ibid.: 1182).

2.5.1 Organisational design strategies

Three main organisational design strategies to manage, align and in general encourage informal face-to-face interaction have been identified in the literature:

a) Creating a work context that encourages and legitimises informal interaction (Purser et al., 1992; Webber, 1993; Davenport and Prusak, 1998; Desouza, 2003; Cohen, 2007; Fayard and Weeks, 2007; Prusak and Weiss, 2007).

b) Developing new flexible forms of organisation (Allen, 1977, 2007; Kraut et al., 1990; Alvesson 1992, 1993; Nonaka, 1994; Grant, 1996b; Cohen, 1998; Davenport and Prusak, 1998; Brown and Duguid, 1998, 2002; Hall, 2001; Teigland and Wasko, 2003; Hoeghl and Schulze, 2005; Haas, 2006; Leonard, 2007).

c) Providing a (physical) space and a time to meet casually and easily (Bahrami and Evans, 1997; Davenport and Prusak, 1998; Hoeghl and Schulze, 2005).[4]

2.5.1.1 Legitimising informal interaction

These strategies aim firstly to create an atmosphere in the firm that makes legitimate spending time talking to other people, whether this is through pre-assigned moments in time and dedicated spaces or through tacit organisational uses and, secondly, to generate and use mechanisms that reward this behaviour specifically. The objective is to embed interaction in the day-to-day functioning of the organisation.

A first type of strategy is that of "slack" time for learning and thinking (Davenport and Prusak, 1998: 93) and developing relationships (Cohen, 2007: 245). "It is important to give people the room and space to talk to each other as knowledge is generated by people at the individual level. Unless people talk and share it with peers knowledge remains untapped (…) informal and emergent structures are a good means to foster tacit knowledge exchange" (Desouza, 2003: 88). Cohen insists that individuals need time to develop relationships and that "they need those moments of time over time" (Cohen, 2007: 245).

A second type of strategy is to promote an explicit "watercooler" culture or "Start talking and get to work!" culture (Webber, 1993: 28; Fayard and Weeks, 2007) in contrast with the traditional management attitude that implies that talking is not working (Davenport and Prusak, 1998: 91). The exchanges realised around the water cooler or similar, open the door to serendipity and the potential to generate new ideas or solve old problems in unexpected ways (Ibid.: 91; Purser et al., 1992; Fayard and Weeks, 2007).

The third type of strategy identified implies building knowledge creation and sharing strategies into performance reviews, compensation decisions and promotion criteria. In companies where "knowledge is power" is the dominant philosophy, organisational incentives have to be aligned with the goals of more effective knowledge-sharing. Incentives are given to workers to share what they know (Prusak and Weiss, 2007: 40). It is about recognition and reward (Cohen 2007:244).

2.5.1.2 New flexible forms of organisation

Flexibility in the formation and implementation of organisational structures allows groups for self-organisation and autonomy to develop rules and/or practices of interaction that best suit their personal interests and those of the organisations and groups they belong to. The objective is the implementation of interaction as a mechanism of information and knowledge exchange.

The first strategy involves the creation of communities of practice, "groups of people who share a concern, a set of problems, or a passion about a topic, and who deepen their knowledge in expertise in this area by interacting on an ongoing basis" (Hoeghl and Schulze, 2005: 267; Brown and Duguid, 1998, 2002). These communities of practice, for their successful functioning, need to provide clear rules for their operation, make provisions for shared cognition, encourage social events for staff and co-locate staff (Hall, 2001: 17).

Another type of strategy relates to the creation of integrator roles and cross-functional taskforces, boundary spanning (Haas, 2006: 1171), or informal self-forming structures, such as conversations and self-forming groups (Davenport and Prusak, 1998). The rationale behind these forms is that human activity creates the organisational mind as individuals interact and trigger behaviour patterns in others. The strategy to accomplish this is to create a "field for interaction", a place in which individual perspectives are articulated. This place is provided in the form of an autonomous, "self-organizing team" made of several members from different departments that meet and interact at the times and places provided by the organisation (Nonaka, 1994: 23; Grant, 1996b: 117-118).

A third strategy involves co-location of staff (Allen, 1977, 2007; Kraut et al., 1990; Alvesson, 1992, 1993; Cohen, 1998; Grant, 1996b; Teigland and Wasko, 2003). Physical proximity is one of the main two factors that make knowledge transfer possible (the other one being the degree to which the knowledge is explicit and therefore easy to manipulate either in verbal, visual, physical or textual form) (Leonard, 2007:61). [5]

2.5.1.3 Creating Physical opportunities for meetings

All the strategies below recognise the importance of providing a physical context, be it inside or outside the firm, in order to encourage informal face-to-face interaction. The objective is to create occasions for informal interactions using one or a combination of the following tactics:

Talk rooms; these are spaces dedicated for informal discussion that workers are expected to use as part of their workday. The expectations are that those conversations will be about work and will create value for the company (Davenport and Prusak, 1998: 93).

Knowledge Fairs and Open Forums create locations and occasions for workers to interact informally, although they also warn that giving people the opportunity to talk to one another does not solve the problem of transferring knowledge and that more formal mechanisms have to accompany informal ones, specially in multinational and distributed companies (Davenport and Prusak, 1998: 93-95)

Management conferences and workshops are usually designed by the Human Resources Departments in big companies in response to changing priorities and business realities to brainstorm for evolving their strategy and the organisation (Bahrami and Evans, 1997: 27).

Finally, **informal events**, such as company days out, bicycle tours or barbecues are organised by the firm in order to encourage informal discussions and informal knowledge sharing (Hoeghl and Schulze, 2005: 267).

Therefore, acculturating the work force, putting into practice flexibility in the organisation of work and the location of workers and implementing policies that bring people together are the three main organisational design strategies found in the literature. In practice organisations can use a combination of the three and also refer to them by different names.

2.5.2 Conclusions

It has been pointed out that one of the challenges faced by knowledge organisations today is dealing with unexpected changes and that the organisational structure has to be flexible enough to cope with those changes. The common characteristics of all the organisational strategies mentioned is that they are organisational arrangements specifically aimed to encourage informal face-to-face interaction between workers and implemented as part of wider organisational strategies. All of them, even the most "informal" forms, are conceived and realised in the formal context of the organisation and "formally" encouraged by it; all of the schemes aim to make face-to-face interaction easy, for it is argued that the easier it is for individuals to interact socially the more likely that interactions – both social and work related – will take place (Hall, 2001: 16), and all of them can be used to increase exchanges of information across internal boundaries and in some cases to extend those exchanges outside the boundaries of the firm.

Organisations that put these policies into practice do so to support overarching strategic priorities rather than to increase the number of physical encounters between their staff members per se. It is clearly a means to an end. These schemes to encourage face-to-face interaction aim to reduce the knowledge transaction costs and strengthen the link between strategy and the management of knowledge activities (Prusak and Weiss, 2007: 42).

2.6 The role of design in the creation of interactive workplaces

In the subject of interaction in organisations, firms and their managers' ideas are very much influenced by the work of organisation theorists. Once organisations realised that it is in the activities around the work itself – such as conversations - that important contributions to the firm are generated, these ideas on management were expressed in the design and interiors of the corporate building (Alvesson, 1992: 196). Design and designers are influenced by their corporate client's ideas on the management of interaction in the workplace.

One way of managing and promoting beneficial interaction dynamics (see point 2.7 for a discussion on the drawbacks of interaction) is through carefully thought-out organisational design and the implementation of new organisational forms. These aim to encourage the formal and informal face-to-face interactions that seem to be the enablers of serendipitous moments of inspiration. Another way is by using the physical structure of the organisation – the building – to express those ideas and to put into practice the management of face-to-face interaction through interior design and layout. There are two approaches that organisation theorists have explored to understand the building and its relationship to the behaviour of its inhabitants, the behavioural and the symbolic (Hatch, 1997: 241-266).

The behavioural or modernist approach focuses mainly on the relationship between the environment and interaction and other forms of activity within the organisation. Interaction behaviour is seen as being shaped by design. The physical structure of an organisation shapes and maintains "a system of activity directed towards the realization of goals" (Ibid.: 251). The symbolic approach, which derives from the symbolic-interpretive perspective[6], advocates, by contrast, that behaviour is shaped by context, understood as the physical location where the behaviour happens plus the meaning that location has for the individual. As Giddens puts it, "knowing where you are triggers specific behavioural routines" (Ibid.253).

These two approaches translate into two ways of looking into the building as facilitator or constrainer of behaviour. Modernist or behaviouralist authors presuppose that changing the physical form of an environment will possibly change the interaction behaviour of the building occupiers. Studies under this perspective have focused on studying the relationship between internal layout and interaction. One way of assessing this relationship is to measure distance between employees' desks and how this affects the possibility of face-to-face interaction (Allen, 1977, 2007). Another way is to investigate the relationship between physical barriers – movable partitions, fixed walls – and face-to-face interaction. This has proven to be positively related to some forms of interaction such as meetings, brief interruptions, confidential conversations and working together (Hatch 1987; 1997: 252; Heerwagen et al., 2004). Despite the fact that these studies have shown that some forms of interaction are more likely to occur in enclosed spaces, many managers and designers alike believe that open office settings with few or no barriers encourage interaction and communication (Becker and Sims, 2001; Rashid et al., 2006).

Symbolic authors, on the other hand, emphasise the importance of the meaning that different locations and spaces have and the interpretation individuals associate to them and how these cues are used to define who they are and what they are doing. These authors claim that there is a link between where you are and how you behave. Studies focus typically on the behaviours caused by the physical context i.e. kneeling in a catholic church, queuing to receive service at a McDonald's restaurant, silence in a library, etc (Hatch, 1997: 253). The building provides useful visual clues to the organisation's identity, social structure and technology that individuals use to interact with others.

With these ideas in mind, managers have involved designers in the creation of office environments and almost uniformly these have produced proposals that show different degrees of openness and layout flexibility to encourage interaction. Hatch gives two explanations for this: one, that some groups claim that sharing their workspaces stimulates creativity and supports teamwork; two, the openness of an environment is associated *symbolically* with open communication (Hatch, 1990, 1997: 252).

2.6.1 Workplace design strategies

Workplace design strategies are usually concerned with the design, use and allocation of the physical facilities which impact formal and informal communication and interaction patterns. They can also deal with the physical symbols which visually reinforce underlying cultural norms and the overall image of the organisation to the outside community (Bahrami and Evans, 1997: 24).

Designing spaces for interaction means creating spaces devoted to knowledge creation or acquisition. These environments are meeting places where knowledge workers can congregate and meet face-to-face. Literature suggests that the best instruments to get work done are conversations (Webber, 1993: 28) that in turn are enabled by face-to-face interaction (Cohen, 1998: 37); and the building, the facility, is the formal structure that facilitates the generation and regeneration of informal socialisation mechanisms (Cousins et al., 2006; Alvesson, 1991, 1992; Hatch, 1997; Hillier, 1996).

All design solutions to encourage interaction in the workplace are rooted in two management ideas related to space. One, that for successful knowledge-exchange and generation adequate time and space need to be devoted to it (Davenport and Prusak, 1998; Nonaka, 1994). Two, open – as opposed to enclosed - spaces are more favourable for facilitating informal encounters, although as has been noted before, this is not always the case (Hatch 1987; 1997: 252; Oseland and Bartlett, 1999; Brennan et al., 2002: 281; Fayard and Weeks, 2007: 606).

2.6.1.1 Spaces for interaction as design strategy

The allocation of space in the building to promote social relations and stimulate the expression and discussion of ideas is one major design strategy for interaction (Alvesson, 1991, 1992). Proposals include versions of what in Japanese firms are called "talk rooms" and in American companies less formalised "locations for conversation" such as the water cooler, coffee machine or cafeteria. More structured places are corporate universities[7] (Davenport and Prusak, 1998: 46).

Physical settings provide contexts for behaviour. They are thought to have influence through their ability to support the range of activities that becomes associated with them and to constrain other forms of activity (Hatch, 1987). The building itself can be designed to encourage interaction. Most common features in workplace design are cafes and lounges, main streets, atria, wider than normal stairways and escalators (Bahrami and Evans, 1997: 24; Cohen, 2007: 244).

The creation of barriers and open spaces to support different types of interaction is also important. A variety of settings, attractors or interaction promoting facilities within the office/building, such as cafeterias, toilets, photocopier rooms, have proven to be effective (Oseland and Bartlett, 1999).

Specific examples found in the literature of workspaces designed for the purpose of encouraging interaction between employees include huddle rooms, common rooms, flexible workspaces, touchdown spaces (Bell and Anderson, 1999), team-oriented bullpens and workstation pods (Becker, 2002). Bell and Anderson prepared an extended list of spaces that could be designed where the focus is on a high level of knowledge-sharing, teamwork and individual concentrated work (Bell and Anderson, 1999). They propose at least eight different spaces:

- Open Team Rooms
- Flexible Workspaces, adjustable by the workers for large or small group interactions by relocating vertical screens and mobile file banks
- Focus Booths, small enclosed spaces for individual concentrated work
- Touchdown spaces, for visitors or short-term use by employees for writing tasks with quick and easy access to data and power capability and telephone
- Closed Team Rooms, assigned and equipped for teams for a specified period of time
- Closed Meeting Rooms, for small groups of three or four workers
- Commons, for social interaction at all levels of the organisation and a place to support individual and informal collaborative work such as IT, writing, reading and telephone
- Huddle rooms, small full-height rooms for one-to-one confidential meetings.

2.6.1.2 Open plan as office design for greater interaction

An open plan office is roughly a public or semi public area in a building with small individual workspaces with high visibility of co-workers, openness and accessibility as its main physical characteristics (Rashid et al., 2006: 826). But there is a problem in defining what an open plan is. Literature generally assumes that the physical characteristics of an open plan office are obvious, but it is difficult to define it rigorously and to find a pure example of *the* open plan layout (Ibid.: 826).

Becker and Simms enumerate the benefits of open plan environments for enabling interaction activities. They found that more open work environments support a higher level of face-to-face interaction, and that the more open office types helped workers form social networks and friendships that directly related to their ease, comfort and trust in asking for help, giving assistance, and clearly understanding project direction and focus, as well as contributing to their job satisfaction. The more open office environments allow higher densities than cubicle or closed offices, and thus contribute to reducing the cost of facilities. Higher densities are associated with a sense of energy and "buzz" until they reach a tipping point, where they become dysfunctional (Becker and Sims, 2001). There is a clear parallel between these findings and the benefits of interaction for firms discussed in section 2.3. In other words, open plan offices appear to enable the conditions for beneficial interaction to happen.

There is also evidence that points to the fact that some forms of interaction are more likely to occur in enclosed spaces, that different spaces support different types of face-to-face interaction and that the amount, duration and regularity of those vary with the type of environment and, possibly, the symbolic context associated to them (Hatch, 1987, 1997; Becker and Sims, 2001). Becker and Sims make an interesting remark about the quality of the interactions on different spaces: "Survey data alone did not distinguish significantly among the office types studied; respondents reported high levels of communication and interaction in all office types. However, in-depth interviews revealed significant differences in the nature and character, as well as frequency of communication and interaction in the different office types"(Becker and Sims, 2001: 46).

Openness or enclosedness is not the only variable that affects the opportunity for interaction. On the one hand, visibility and the accessibility of spaces are key spatial variables that facilitate spontaneous face-to-face interactions; on the other hand, the type of work and the type of company affects interaction too. A good open plan office design that aims to encourage interaction needs to balance an open layout with the power to control one's surroundings and the degree of personal privacy (Fayard and Weeks, 2007).

2.6.2 Conclusions

Designing for workplace interaction could be then defined as creating environments for workers to engage in a range of informal interaction activities, from conversations to spontaneous meetings, where workers feel comfortable – authorised, enabled and with a certain amount of privacy - to do so, hoping that in the process, the invisible mechanisms that trigger knowledge-transfer and innovation, are generated and, through time, regenerated.

Unfortunately, designing for interaction doesn't help without managers' recognition that informal mechanisms are first, a key activity for business success and second, a process that can be nurtured (Davenport and Prusak, 1998: 67). To encourage interaction through design, the strategic orientation of the businesses towards the value of face-to-face interaction needs to be made a management commitment and a measure of success.

2.7 Beneficial and non beneficial interaction: organisational and design drawbacks

2.7.1 The management perspective

Organisational and design efforts to increase interactions can create problems that firms must address successfully at different levels to perform well. In excess, the benefits for companies described in section 1.3 – trust, facilitating the flow of ideas and social reasons, have their drawbacks too. As much as face-to-face interaction is essential to the process of building social relationships and trust, managers who adopt this strategy are threatened by a loss of control over their employees (Webber, 1993).

Trust puts the participants in the relationship in a position of vulnerability, for they must open up to the others, which is unnerving. This in turn creates the possibility of disagreement and conflict, which is perceived as destructive, a sign of betrayal and disloyalty. Finally, as no two people will see the same event in the same way, trust acknowledges the possibility of ambiguity and strives to negotiate it. This manifests in a perceived undermining of the manager's authority. But trying to avoid the strategy of building trust inside the firm will negatively affect knowledge creation inside the organisation (Ibid.: 41). Also, a high level of trust allows relationships to run smoothly but may reduce the incentive to acquire new knowledge somewhere else (Cousins et al., 2006).

Stimulating the flow of ideas through interaction can both transform and harm the performance of groups if information overload occurs (Haas, 2006: 1170). Teams need to be enabled by the organisation to handle this problem, using some of the strategies mentioned in section 2.4. Authors also warn that giving people the opportunity to talk to one another does not solve the more general issue of transferring knowledge and that more formal mechanisms have to accompany informal ones, specially in multinational and distributed companies (Davenport and Prusak, 1998: 93-95).

Finally, valuing interaction for social reasons can become, in excess, a barrier to solo work. An excess of interaction in one's daily work can easily be perceived by individuals as systematically unhelpful and can create highly stressful interruptions (Heerwagen et al., 2006). Having one's personal space intruded too often results in a lack of control of the flow of interpersonal interactions and of one's assigned work time (Altman, 1975; Altman et al., 1981: 151; McGrath and Kelly, 1986: 66; Perlow, 1999: 59).

2.7.2 The design perspective

The debate of designing for interaction runs close to the matter of communication versus concentration, which in return is at the core of arguments over whether open plan is preferable to cellular offices. Using the layout of a building to encourage interaction in the workplace can produce effects that are not always desirable. The lack of physical barriers doesn't necessarily mean more interaction but it does mean loss of privacy and an increase in noise, distractions and interruptions, which in turn leads to higher levels of stress. It is important therefore for individuals to be able to disengage from interaction, either through flexible design or through specific organisational guides (Oseland and Bartlett, 1999; Heerwagen et al., 2004, 2006).

The British council for Offices points out that this debate involves: *"...complex issues of privacy, individual creativity and the encouragement of innovation and knowledge management within the organisation studied. The fact that a definitive causal relationship has not been found indicates the extent to which the answer is dependent upon the unique characteristics of individual organisations. […] Empirical findings illustrate a paradox of knowledge management: the best transfers are serendipitous, personal and private, yet the best insights need periods of intense and private reflection as well as periods of exposed communal activity. The challenge is balancing the organisation's requirements for both communication and concentration, and devising spaces that can respond to and catalyse the highly complex process of social interaction at work"* (BCO, 2006: 48).

2.7.3 Conclusions

Interaction is highly desirable for companies who want to increase the possibilities for knowledge-transfer and innovation, but the literature suggests there are drawbacks to its encouragement. An understanding of the company's culture and strategic orientation, and of the workers composition and behaviour should inform any project focused on promoting face-to-face interaction in the organisation.[8]

2.8 Interaction, knowledge transfer and innovation

Informal face-to-face interaction in the form of conversations and serendipitous encounters between individuals in their workplace, are "the means of production" (Price, 2007: 109) by which knowledge is exchanged and innovation created in organisations. These conversations are influenced not only by the specific organisational environment but also by the physical environment where they take place and which is viewed as an enabler of the process (Ibid.: 105).

There is a widely quoted body of literature that relates informal face-to-face interaction, conversations and serendipitous encounters, to knowledge-transfer and innovation. Allen suggests in his 1977 work that informal, serendipitous interactions and chance encounters lead to more innovation (Allen, 1977). Nonaka defines innovation as a key form of organisational knowledge creation, which cannot be explained merely as information processing or problem solving, but as a "process in which the organization creates and defines problems and then actively develops new knowledge to solve them" (Nonaka, 1994: 14). Knowledge is created and organised by the very flow of information (Ibid.: 15) but whereas explicit knowledge is "codified knowledge (…) (and therefore) transmittable in formal, systematic language" be it hardware, software or processes, tacit knowledge is "…a continuous activity of knowing"(Ibid.: 16) which makes it hard to formalise and communicate.

Leonard and Sensiper affirm that "Innovation […] depends upon the individual and collective expertise of employees" (Leonard and Sensiper, 1998: 112). The part of expertise that is tacit is essential to the innovation process (Ibid.: 112). Using creative and innovative solutions to solve complex problems is said to be a key characteristic of the knowledge firm (Alvesson, 2001). Creative ideas do not arise spontaneously from the air but are born out of conscious, semiconscious, and unconscious mental sorting, grouping, matching, and melding (Leonard and Sensiper, 1998: 115).

Moreover, interpersonal interactions at the conscious level stimulate and enhance these activities (Ibid.: 115; Nurmi, 1998). Knowledge primarily in the heads of people flows through an organisation as the result of informal social networks more than formal programs and processes (Mascitelli, 2000; Dixon, 2000; Brown and Duguid, 1998, 2002). As Davenport and Prusak put it, "It is the value added by people - context, experience, and interpretation - that transforms data and information into knowledge." (Davenport and Prusak, 1998: 129). Knowledge is primarily a function and consequence of the meeting and the interaction of minds. Human intervention remains the only source of knowledge generation (Fahey and Prusak, 1998: 273) and interplay among individuals appears essential to the innovation process. (Leonard and Sensiper, 1998: 115).

In order to make these encounters and conversations possible, a physical context where those exchanges take place needs to be provided (McLennan, 2000). Relatively recent research provides evidence suggesting that the physical environment of an organisation affects the process by which people with their knowledge produce results for an organisation. The workplace is seen as an enabler of or an influence over that process (Price, 2007: 108). Specific workplace design strategies have been discussed in section 2.5.1, and the fruitless debate between advocates of open plan versus cellular office design exposed in 2.6.1. The conclusion seems to be that modern flexible workspaces combining degrees of openness and closed-ness are those which best encourage conversations with others and conversations with oneself, or interaction and self-reflection periods (Ibid.: 105; BCO, 2006; Haynes, 2008: 300).

Is it impossible, in the light of the arguments presented, to dismiss the link between informal interaction (conversations that facilitate knowledge transfer and exchange and the assimilation of valuable business information and practices), and innovation (that intangible process that is "the source of sustained advantage for most companies" (Leonard and Sensiper, 1998: 112). It is not possible either to reject the evidence that the physical environment of an organisation influences the occurrence of those conversations. Face-to-face interaction is therefore one of the key preconditions that make information and knowledge gathering, creation and exchange possible. It is a key mechanism in the process of organisational innovation and the physical environment where it takes place facilitates its occurrence. As such, interaction behaviour and the workplace need to be contemplated by the firm's management strategy and treated as manageable organisational assets. The development and assimilation by the organisation of good interaction practices and the design of workplaces that support "the optimum blend of interaction and quiet reflection" (Price, 2007: 115) can help directly towards the formation of innovative ideas and solutions.

These arguments cannot be easily ignored in the view of current research and successful practice. What can be challenged is the lack of established tools that allow the extent of the connection to be measured. The next two chapters deal with that particular issue in theoretical and methodological detail.

2.9 Summary Chapter 2

This chapter has argued for presenting interaction in the workplace as a multifaceted phenomenon embedded in the operation of the complex institution that is the organisation and as a mechanism valued by those companies that perceive their human capital as key to the success of the business. Specifically, informal face-to-face interaction has been presented as essential to the knowledge-transfer and creation processes and as the type of interaction that most benefits firms since it leads to the building of trust, facilitates the flow of ideas and creativity in the organisation and is highly valued by knowledge workers in the accomplishment of knowledge work. Informal face-to-face interaction is also a key mechanism in the process of organisational innovation. With the recognition of its importance in getting work done and its link to innovation comes the recognition of the need to create processes, structures and environments that enable workers to interact. Such an important device needs to be contemplated by the firm's management strategy and treated as a manageable organisational asset.

The devising of organisational and design strategies to encourage interaction could be then defined as creating structures and policies and a variety of environments for workers to engage in a range of informal interaction activities, from conversations to spontaneous meetings, where workers feel comfortable to do so. This is implemented with the hope that in the process the intangible mechanisms that trigger knowledge transfer and innovation are generated and, through time, valued and regenerated. In this process, managers' recognition that informal mechanisms are first, a key activity for business success and, second, a process that can be nurtured (Davenport and Prusak, 1998: 67) is a must. To encourage interaction in an organisation the businesses strategic orientation towards the value of informal face-to-face interaction needs to be made a management commitment. In this context, the development and assimilation by the organisation of good interaction practices can help directly towards the formation of innovative ideas and solutions. But *informal physical interaction cannot be manufactured*. Making a conscious effort in devising strategies to encourage it doesn't imply that the benefits associated with it are automatically achieved. No exhortation to workers to talk to each other can make them do it if they don't want to. And if they do it doesn't mean they will develop relationships of trust. No assigning of employees to communities of practice can make those real and successful. No fancy new café area can force people to spend time talking in it if they don't feel they are allowed to do it or if the space is not adequate (i.e. lack of privacy for confidential conversations). However, firms can take action to encourage it to happen, and need to be persistent and subtle (Cohen, 2007: 242). It is about creating a shared context (Nonaka and Toyama, 2007) where facilitating interactions leads to increased communication, the development of trust and close working relationships (Cohen, 2007: 243). Bourdieu observes "(T)he existence of connections is not a natural given…it is the product of an endless effort at institution" (Bourdieu, 1986: 249). In conclusion, managers and designers should aim to *create the conditions favourable to informal face-to-face interaction* rather than to plan for it. So, if the way forward is to create the conditions favourable to informal face-to-face interaction, the next question is: what are those conditions?

This idea of interaction as a process that can not be fabricated but that is essential to knowledge acquisition, transfer and creation can be found underlying the questions that Davenport and Prusak asked to managers barely a decade ago: "when people, technology, products and the business environment change over time, what is left? (…) What creates the *continuity* that allows particular firms to thrive over time? We strongly believe that the way firms generate and pass on knowledge is an essential part of that continuity." (Davenport and Prusak, 1998: XIII). They are referring to the strategic orientation to knowledge and to the mechanisms and strategies that make its creation possible.

This assertion brings into the picture another concern which is related to the methodologies used to understand and measure those mechanisms, that of continuity. The role informal face-to-face interaction plays in the organisational knowledge process is largely based on a collection of work that, although highly influential, is mostly opinion based on loose and unsystematic observations. Also, this work has been conducted in the context of wider organisational subjects, as Goffman pointed out "interaction practices have been used to illuminate other things, but themselves are treated as though they did not need to be defined or were not worth defining" (1971: IX). This chapter's literature review suggests that a more dedicated take on it would bring into the field novel insights to the discussed link to innovation. Another question which this thesis leads to is: how good are current methods to understand and measure informal face-to-face interaction in organisations.

Chapter 3 deals with the identification of the basic preconditions and the key circumstances that enable face-to-face interaction. A review of literature focused on some of the specific dimensions of these preconditions is conducted and an assessment is made of the methods currently used in their study. It is argued that a richer method to study the pervasive nature of interaction dynamics is necessary (McGrath and Kelly, 1986). Chapter 4 describes the method this thesis proposes to fulfil those requirements.

Key Points

- Informal face-to-face interaction:
- Is key for the transfer of established knowledge and the creation of new knowledge.
- Is the most frequent activity in today's workplaces.
- Encourages the flow of ideas inside the firm, builds trust and is highly valued by workers for various social reasons.
- Typical organisational strategies to encourage interaction deal with its legitimisation, a degree of flexibility of structures and the provision of physical opportunities for encounters.

- Workplace designers aim to comply with management demands, translating into spatial settings management ideas on interaction dynamics.

- Open plan office design has been, and still is, the most common spatial strategy, although plenty of research has pointed toward its drawbacks for interaction.

- There is a paradox in the management of knowledge: individuals need periods of contact with others to exchange information, as well as periods of solitary time to reflect and assimilate that information.

- There is a link between interaction and innovation via knowledge exchange processes. The design of the physical context where this activity takes place influences its outcome.

Notes

1 In the context of this thesis organisation, firm and company are used interchangeably. These are considered the strategic level of decision making. Workplace and office environment are also used interchangeably. These are considered to be the operational level of implementing decisions in the form of organisational structure and design policies and strategies.

2 The method is only "potentially" longitudinal as long as the data spans years, or decades. That is, the system collecting the raw data needs to be deployed for an extended period of time to affirm that the method/approach is longitudinal. The benefits of adopting a longitudinal approach are discussed in Chapter 4 Methodology.

3 This thesis does not explore the role that information technology plays in interaction patterns. This research investigates the potential future role that location tracking systems have in the study of physical interaction in the workplace.

4 This point presents briefly some organisational strategies that use space to encourage interaction. Point 2.6 presents specific design strategies developed based on these ideas and taken to a different level of concretisation.

5 One of the implications that the knowledge based view of the firm has with regard to the distribution of decision making inside the firm concerns "co-location of decision making and knowledge" (Grant, 1996b: 119). If knowledge resides in employees and the knowledge needed to resolve a particular problem can be concentrated at a single point in the organisation, then centralised decision making is feasible. But because there are different types of knowledge, and not all knowledge is easy to transfer and aggregate, co-locating individuals is not always the solution. Grant argues that decisions requiring knowledge that is easily transferred and aggregated, i.e. statistical knowledge, can be centralised, whereas decisions based upon explicit and tacit knowledge which is specific and costly to transfer, i.e. "strategic planning, investment appraisal" (Grant, 1996b: 119) should be decentralised. Teigland and Wasko, exploring Grant's ideas on co-location, discovered that "high reliance on collocated coworkers results in lower levels of creativity (…) (which) suggests that the knowledge of collocated coworkers may be largely redundant and the integration of this local knowledge, although efficient, may stifle the development of new ideas and innovations"(Teigland and Wasko, 2003: 278). One of the factors that prevents knowledge from being transferred is its localness. "People usually get knowledge from their organizational neighbours" (Davenport and Prusak, 1998: 41), because they trust them and because they are physically close. "Face-to-face meetings are often the best way to get knowledge" and people won't deal with the "effort and uncertainty of trying to discover who in the company may know more" (Ibid.: 41). People tend to settle for the knowledge or information that is "good enough" for their purposes" and not for the best possible knowledge (Ibid.: 41). This localness adds to the inefficiency in transferring knowledge, and is supported by Grant's work and Teigland and Wasko's later experiments.

6 Symbolic–interpretivism sees the organisation as a social construction that is reconstructed continuously and can potentially be changed in the reconstruction process (Hatch, 1997: 42).

7 Corporate Universities are educational entities conceived as strategic tools to assist the parent organisation in achieving its goals by conducting activities that foster individual and organisational learning and knowledge (Allen, 2002: 9).

8 Rashid et al. in their study of the effects of spatial layout on face-to-face interaction came across the existence of different spatial cultures of interaction in the organisations studied. These organisations had redesigned their offices to meet different organisational needs including the need to increase face-to-face interaction. But despite designing public and semi-public spaces to encourage interaction, workers in the four organisations preferred by far to interact in individual's workspaces and to some extent in corridors and some common areas. They observed a workspace culture, a corridor culture and a common-area culture that hadn't been designed for. They argue that firms need to understand first their specific spatial cultures and then support them through the right spaces (Rashid et al. 2006). This study is interesting for it did not intend to

explore the cultural dimensions of interaction and still the authors suggest that people not using the spaces assigned for it might be a consequence of staff resistance to the new office strategies or a bad managerial approach to the encouragement of cultural change. They conclude that "…spatial layout on its own might be insufficient to generate, sustain, and increase interaction without the necessary changes in the attitudes, programs, and policies of an organisation" (Rashid et al., 2006: 842).

Chapter Three:
Pre-conditions and Measurements for Face-to-Face Interaction

Abstract

The objective of this chapter is the description of face-to-face interaction as a phenomenon in its own right, identifying first the conditions that enable it and, secondly, a set of criteria for its measurement, focusing on the workplace context. The section opens with an overview of Goffman's research on face-to-face interaction that defines it as circumscribed in space and time. His research provides a conceptual map that inspires a further cross discipline literature review driven by the need of finding operational concepts. This exercise identifies key spatial concepts – Personal Space, Interaction Distance, Interpersonal Boundaries Regulation – spatial attributes – location, visibility – and temporal dimensions – amount, duration, frequency, sequence – that become the building blocks of the method this thesis develops and presents in the next chapter. The examination of research also reveals two other interesting aspects of face-to-face interaction dynamics. On one hand, it identifies currently understudied spatial and temporal dimensions of face-to-face interaction that can contribute to a better understanding of work dynamics and to improve work structures and office designs. On the other hand, the review of current methods used to study physical interaction in organisations confirms the need for a holistic - ***real-time, multiparty, continuous and longitudinal*** *- picture of its dynamics. The chapter closes by speculating whether new technologies could possibly help to bridge this gap directed by the operational concepts identified.*

3.1 Introduction

The organisation of behaviour in face-to-face interaction is "a primordial problem in human relations" (Kendon et al., 1975: V). Fascinating as it is, face-to-face interaction or the behaviour of people when facing one another in small groups[1] (Ibid.: V) has been studied by a wide range of disciplines in the social sciences – psychology, sociology, social psychology, anthropology and linguistics among others. When the study of interaction involves the spatial dimension, the list expands to the fields of environmental psychology, human geography, urban planning, architecture and environmental design. Almost every field has developed very specific approaches to the study of encounters focusing on different aspects of them. Two consequences of this plurality of approaches are, on one side, the richness of ideas and techniques and their potential cross-fertilisation, and on the other side, confusion and lack of consistency at the level of concepts and terminology (Ciolek, 1983: 55).

The study of interaction has a long tradition in the social sciences. The early sociologist Simmel[2] believed that the main concern of sociology should be with the phenomena of face-to-face interaction for "SOCIETY is merely the name for a number of individuals, connected by interaction" (Coser, 1965: 5). His work had an important influence in the Chicago School of descriptive sociology that focused on behaviour in face-to-face situations. Paralleling this development and closely related to it was the growth of symbolic-interactionism developed by C.H. Cooley (1902) and later by G.H. Mead (1934), who emphasized the importance of interaction for throwing light over social psychology concepts such as the "self" which is seen as "a product of interaction" (Kendon et al., 1975: 2). In anthropology, the emergence of functionalism led to an interest in the interrelationships between people and a concern with how they behaved in each other's presence. All these ideas, developed during the first half of the twentieth century, set the background for the emergence of empirical studies of interaction (Kendon, 1988: 20). Different approaches were developed from then onwards, contrasting sharply with previous ones that studied interaction for the sake of other higher concepts such as the structure of social institutions or the nature of human relationships (Kendon et al., 1975: 2). The new wave of research will focus on "the behaviour of face-to-face interaction and how it functions interactively"(Ibid.: 2). Of all the authors in the disciplines that have made the study of human interaction their focal point, perhaps Goffman is the one who still has theoretical and practical relevance, and is closest to the focus of this thesis. Many subdisciplines have developed in the last 50 years in the study of specific aspects of face-to-face interaction – i.e. cognitive anthropology, conversational analysis, ethology, ethnomethodology, exchange theory, kinesics, network analysis, sociolinguistics and symbolic analysis. The effort to review the developments in each of these fields is beyond the scope of this thesis.

Specifically, the study of interaction in the workplace suffers from two main problems. Firstly, it has not been a research priority per se being just a small part in wider and primary organisational concerns such as "organizational structure and strategies, workforce attitudes and preferences and technology integration" (McCoy, 2002: 444). Interaction has been seen as a tool to achieve higher overarching strategies. The focus of much research has been on how the physical workplace can best support new organisational structures and technologies, and at the same time attract and retain the best people (Ibid.: 444). Secondly, this area endures the advantages as well as the disadvantages of the plurality of approaches mentioned above. The most obvious consequence is the lack of a common theoretical framework and methodology for the study of face-to-face interaction in the workplace. The lack of a holistic approach encompassing spatial and time aspects of interaction is evident from a review of literature across these fields.

This thesis aims to develop a new method to study face-to-face interaction in office buildings. A method which in order to be constructed needs to identify its building blocks;these elements and concepts concerning the conditions that make face-to-face interaction possible. Once these conditions are identified and operational concepts defined, the methodology can be formulated.

The conditions are identified through a review of research which, as a common denominator, assumes that *for face-to-face interaction to happen a number of spatial and time conditions need to occur*. This research acknowledges how interaction emerges out of the physical and social world where it takes place (Collins, 1988: 63), and it draws on theoretical and empirical work from different fields and on different aspects of the spatial and temporal conditions that enable face-to-face interaction in organisations. A conscious multidisciplinary effort has been made to bring together perspectives that will allow for the creation of a method that aims to offer unprecedented understanding of the nature of interaction in organisations.

3.2 Pre Conditions for Face-to-Face Interaction

The sociologist Ervin Goffman was a pioneer in the study of the processes and structures specific to face-to-face interaction from a micro-sociology perspective[3]. His influence has been enormous in the area of interaction research as well as in other fields of sociological thinking – the self and identity, affect and emotion, sex and gender and status structures (Branaman, 2003: 86).

Goffman advocated the study of interaction as a domain in itself as a separate branch of sociology (Kendon, 1988: 18). In his last published paper, "The Interaction Order", he addressed the American Sociological Association as its President and provided a definitive overview of his work in this field: "In my remarks to you tonight, I want to sum up the case for treating the interaction order as a substantive domain in its own right" (Goffman, 1983: 2). He distanced himself from existing traditions in the study of interaction and made clear that his main concern was "to raise the question as to how interaction is possible in the first place" (Kendon, 1988: 19). This aligns with the general objective of this thesis, and sets up the basic theoretical ground for the methodology.

3.2.1 Erving Goffman and the Interaction Order

It is a fact of the human condition - Goffman argues - that our daily life is usually spent in the immediate presence of others, the activities people pursue in a day-to-day basis being therefore socially situated (Goffman, 1983: 2). Face-to-face interaction is defined as the reciprocal influence of individuals upon one another's actions when in one another's immediate physical presence (Goffman, 1953, 1983). He argues that spending most of our daily life in the presence of others - that is "socially situated" - has some consequences or "effects" that are indicators of social structures and that these effects should be treated "as data in their own terms" (Goffman 1983:2). To do this, the researcher needs to "differently conceptualize these effects, great or small, so that they can be extracted and analyzed […] pieced out and catalogued sociologically, allowing what is intrinsic to interactional life to be exposed thereby."(Ibid.: 3). Without any pretence of replicating the research he conducted in public places or in the home, this insightful comment has been picked up by this thesis and inspired the method development described in the next chapter.

Goffman's vision of face-to-face interaction is that it is always part of a larger fundamental frame, which sets "the conditions for what can emerge within it" (Collins, 1988: 51). This frame is a multilayered continuum and its three primary components are:

- The *physical world* - "the natural world of physical objects in which people live including their own bodies" (Ibid.: 59).
- The *social ecology* - the **physical bodies** of the people that happen to be present (Ibid.: 52) […] and the **distance** between them (Ibid.:

61) […] as well as the social world and of other people and their networks of relationships" (Ibid.: 59).

- The *institutional setting* which is "a frame which arises inside these two outermost frames: the physical world and the ecological co-presence of physical human bodies" (Ibid.: 53). Examples of institutional settings are an office building and a library (Goffman, 1966: 20).

Later, and in addition to the multiple aspects of space he deals with throughout his work, he includes the aspect of *time* as one of the essential descriptors of face-to-face interaction "Whatever is distinctive to face-to-face interaction is likely to be relatively circumscribed in space and most certainly in time" (Goffman, 1983: 3). This multilayered frame enables and affects the form of interaction. The concepts Goffman developed to describe it and those that are more relevant to this research are his definitions of types of co-presence; the role the physical environment plays in the form of interaction that takes place; the spacing conditions of contacts and his take on time.

3.2.1.1 The importance of physical co-presence

In regard to space, Goffman stresses the importance of physical co-presence through "contacts" and "encounters" as one of the basic units of interaction. Examples are "sightings and exchanges […] a passing street glance, a conversation, an exchange of increasingly attenuated greetings while circulating at a sociable gathering, an attendee's-eye-view of a platform speaker" (Goffman, 1983: 7).

Co-presence therefore does not necessarily imply verbal communication. Goffman considers that once individuals come into one another's immediate physical presence "the line of our visual regard, the intensity of our involvement, and the shape of our initial actions, allow others to glean our immediate intent and purpose, and all this whether or not we are engaged in talk with them at the time" (Ibid.: 3). Other authors recognise that in everyday situations among normal people "speech does only part of the work it is usually thought to do" (Kendon et al., 1975:13). Co-presence might be enough then to talk about reciprocal influence, and therefore interact through non-verbal behaviour, "gestures, if you will" (Goffman, 1983: 3).

Goffman dissects the condition of immediate physical presence and defines the terms *gathering*, *situation* and *social occasion* to use when describing co-presence behaviour in face-to-face interaction (Goffman 1966:18).

A gathering is a "set of two or more individuals whose members include all and only those who are at the moment in one another's immediate presence" (Ibid.: 18). It is an assembly of people engaged in *focused interaction*. These are occasions on which people openly cooperate in one another's presence to sustain some form of joint activity (Goffman 1983). Such occasion are exemplified by "duels, conversations, interviews, musical performances, loading a cart, open heart operations, and dancing" (Ciolek 1983: 63). The type of gathering this thesis focuses on is face-to-face conversations in the workplace.

A situation is the "full spatial environment anywhere within which an entering person becomes a member of the gathering that is (or does become) present (Goffman, 1966:18). Gathering are situated when they occur within the physical boundaries of a situation (Ibid.: 21). An example of a situation is the workplace environment. This is a "wider social affair, undertaking, or event, bounded in regard to place and time and typically facilitated by fixed equipment"(Ibid.:18). A social occasion provides the context that structures the situations and gatherings and in which those tend to "form, dissolve

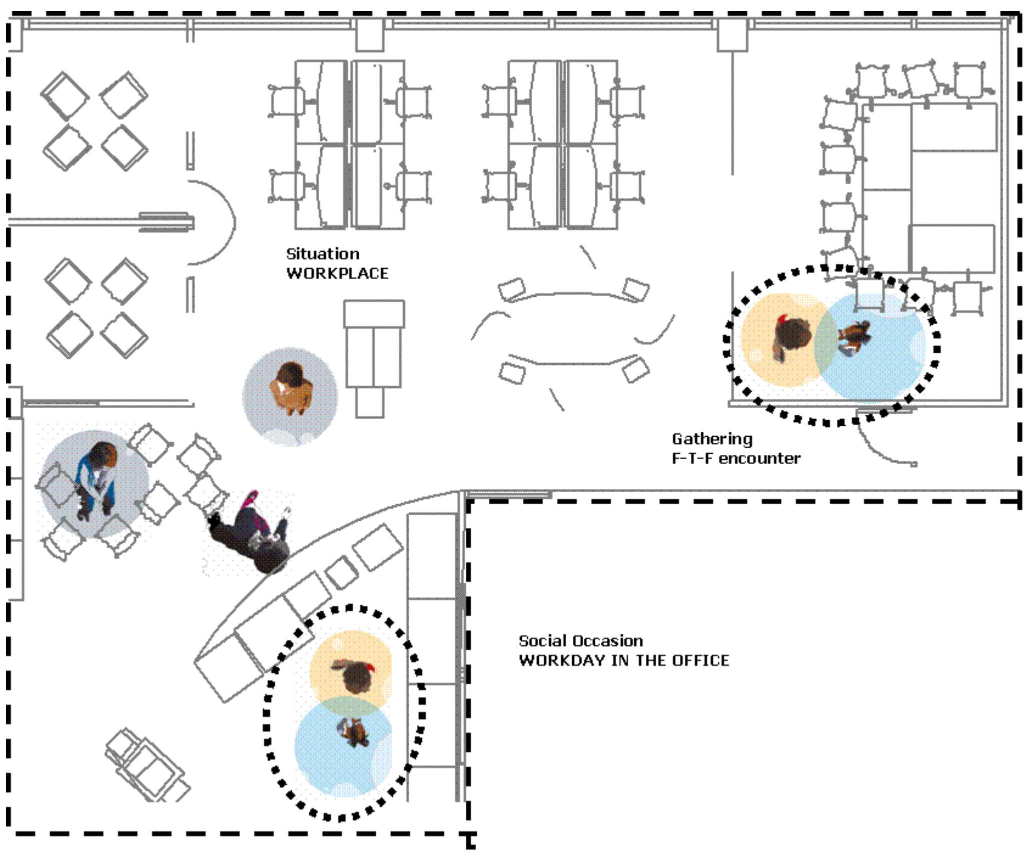


Figure 3.1 Example of Goffman's types of physical co-presence in an office environment.

and re-form, while a pattern of conduct tends to be recognized as the appropriate and (often) official or intended one" (Ibid.: 18). An example of a social occasion is "a workday in the office" (Ibid.: 18). Although Goffman recognises the complications associated with this concept, he affirms that some such term must be used because when a gathering takes place "it does so under the auspices of a wider entity of this kind" (Ibid.: 20).

The relationship between the terms is one of containment and implies a degree of order: "the regulations of conduct characteristic in situations and their gatherings are largely traceable to the social occasion in which they occur" (Ibid.: 20). In other words, a social occasion such as a workday in the office becomes the background against which gatherings and situations occur. See figure 3.2.

3.2.1.2 Space, Spacing and Time

Goffman's work drew attention to spatial and temporal aspects of interaction that had been previously overlooked. He pointed out the importance of specific aspects of behaviour in interaction which serve in boundary maintenance and that are essential to our understanding of how interaction is accomplished. He seem to speak of temporal and spatial "brackets" that establish the boundaries of the encounter (Giddens, 1988: 261).

As Goffman defined it, interaction is "inherently circumscribed in time-space" (Ibid.: 260). Timing and spacing characterises encounters and he gave indications as to what to look for. He pointed out some of the mechanisms that help maintain interaction boundaries: the physical environment, spacing between bodies, beginning and end of encounters and duration of the gatherings.

The physical environment where the encounters take place affects on one hand the type of available co-presence – by focusing it, and on the other, influences the "spacing of contacts undertaken" (Ibid.: 261). Goffman argues that manifestations of interactions such as queues or conversations have particular and characteristic spatial organisation and boundaries and those would-be members should observe those boundaries, otherwise they may not be regarded as qualifying as members of the queue or of the conversation and so may not hold a place in it. To engage in queuing or in conversation participants must join in and sustain a spatial arrangement.

Participants cooperate to maintain the spatial arrangement by respecting the physical boundaries of the interaction and through the spacing between the bodies. In the case of conversations "people manoeuvre in relation to one another so that the little world of talk that they establish is maintained" (Kendon, 1988: 28), since people must be close enough to hear and see one another (Ibid.: 32). Another aspect of this is that "around each occasion of talk there is a sort of no-man's land, a reserve of buffer space. People may pass through such spaces, but when they do so, as a rule, they distanced the gatherings within them. If they stay […] they are likely to be let in to it, or invited to join" (Ibid.: 29). The spacing of individuals within encounters is essential to the form they take[4].

The character of the physical setting and the spacing between participants are not the only factors circumscribing encounters, temporal aspects help to bind them. For face-to-face interaction to happen the "engrossment and involvement of the participants" and their attention is critical; but attention cannot be sustained for very long. In order for the interaction to survive it has to be brief, for "these cognitive states cannot be sustained for extended periods of time" (Goffman, 1983: 3).

Encounters are limited by the "character of the physical setting" or "bounding spatial brackets" and by indicators, signs or "markers" that establish their beginning and their end or "temporal brackets" (Giddens, 1988: 261). Goffman affirms "…one may speak, then, of opening and closing temporal brackets and bounding spatial brackets" (Goffman, 1974: 251-252). Giddens argue that the time – space zoning of encounters is fundamental to the type of interaction occurring (Giddens, 1988:261).

3.2.1.3 Goffman's legacy and limitations

For this thesis, the legacy of Goffman is twofold. On one hand, it relates to the assumption that space and time are two of the fundamental conditions that enable face-to-face interaction. For face-to-face interaction to take place it is necessary to be in close physical presence in order to be able to influence each other's behaviour; it needs to be circumscribed to a point in time and it has duration, a beginning and an end. On the other hand, his work provides a conceptual map and a set of classifications to apply to the investigation of face-to-face interaction. This thesis considers: one particular social situation – the workplace ; a type of gathering –informal focused interaction; a type of social occasion – workdays in the office; and the institutional setting – the organisation and its building/s.

Face-to-face interaction is therefore grounded in the overlay of spatial, temporal and institutional contexts. See table 3.1 for a summary of Goffman's concepts used in this thesis.

Goffman's work was widely criticised. His work was often disclaimed and judged as trivial (Collins, 1988). His numerous critics question some of the assumptions from which his conclusions were drawn and mainly censure him for being unsystematic (Gouldner, 1970; Schegloff, 1988). But many other authors, including this thesis', have considered and still deem Goffman as the greatest sociologist of the second half of the twentieth century and a true inspiration for their work.

Face-to-Face Interaction Preconditions

SPATIAL	Physical Presence Spacing of Bodies Respect of Physical Boundaries	*Gathering*
	Physical Environment	*Situation*
TEMPORAL	Brief (duration) Point in time (beginning and end)	*Gathering*

Table 3.1 Conceptual map of face-to-face interaction based on Goffman's interaction order applied to the study of face-to-face interaction in the workplace (Goffman, 1983).

3.2.1.4 Gaps and next steps

Goffman focused on investigating "the issue of what it takes for people to "do" interacting" (Kendon, 1988: 20). His work provides a framework and some terminology with which the complexities of interaction can be talked about (Ibid.: 38). He gives indications as to what to look for, the means by which interaction is accomplished. This is the reason why his work is the theoretical cornerstone of the thesis.

Goffman not only provides this thesis with the preconditions for human physical interaction he also inspires the method this thesis aims to build. Like Goffman, this thesis is concerned with the behaviour of individuals while engaged in a situation, and it draws upon the norms or rules guiding that behaviour, "the traffic rules of interaction" (Kendon 1988:15). The main methodological objective of this work aims to measure objective manifestations of behaviour in face-to-face encounters.

His work identifies that there are rules of access, regulations and boundaries to gatherings, and this thesis applies this knowledge to the study of physical encounters. However, his research does not answer specific questions on those rules such as how to measure distance between bodies[5]; how to approach the physical environment as an assessable variable; how long an informal face-to-face interaction lasts; what other dimensions of time affect interaction in the workplace. A need to identify further research in these areas is paramount for advancing the identification of the building blocks in the new method to study face-to-face interaction in the workplace.

3.3 Finding operational concepts

3.3.1 The micro-space in interpersonal dynamics

Goffman identifies three key spatial issues, see Table 3.1, that firstly make face-to-face interaction possible and secondly, regulate co-presence during the encounter. These are immediate physical presence, the spacing of bodies and respecting the physical boundaries of the encounter type. Research on the regulation of the space around bodies was pioneered by Hall (1959, 1966) and Sommer (1959, 1969) who, building on the work of ethologists and zoologists, launched the concept of personal space in the late 1950s/ early 1960s (Aiello, 1987). But it was Hall with his studies on Proxemics who quantified the "micro-space of interpersonal encounters" (Hall, 1968: 83).

I. Altman and collaborators (Altman, 1975, 1976; Altman et al., 1981; Werner et al., 1992) with their research on personal space, privacy and territoriality, complement the perspective on face-to-face interaction dynamics. The rules of interaction that Goffman describes cannot be understood without exploring the multifaceted aspects that regulate interpersonal boundaries and the consequences of invading individuals' personal spaces at work.

Their attempts to measure interaction distance have been merged in this thesis to provide the operational concepts, measuring instruments, that define states of interaction and solitary time.

3.3.1.1 Personal Space and Interaction Distance

In the 1950s there was very little research published on how people used space and specifically on interaction distances among individuals (Sommer 1959, 2002). Studying spacing mechanisms in animals and applying concepts such as individual distance – "the amount of space between organisms and their conspecifics" (Sommer, 2002: 647), and flight distance – "the amount of space between individuals and members of other species seen as potential predators[6]" (Ibid.: 647), Sommer, Hall and others after them initiated research on interpersonal spacing in humans. The motivations of these authors were similar. Understanding the way people use space would assist in improving the quality of design of buildings, hospitals, homes, offices and the built environment in general (Sommer, 1959, 1969; Hall, 1966, 1968). The term *personal space* was introduced by Sommer in 1959 and became a starting point of the subsequent "intensive and systematic research into human spatial behaviour" (Ciolek, 1983: 69).

Personal space is a term used in social psychology to describe "the emotionally tinged zone around the human body that people feel is their space" (Sommer, 1959, 2002: 647). Its dimensions are not fixed and vary according to "internal states, culture and context" (Sommer, 2002: 647; Hall, 1966). It refers to a solitary person's spatial domain, usually defined as a bubble and variously shaped – circular, elliptical or hourglass shaped. It has been described as an invisible boundary with the body at its centre which surrounds an individual and moves with him[7] (Ciolek, 1983; Hall, 1966; Sommer, 2002). When an individual interacts with others, in what Goffman called *focused interaction*, he surrenders part of his personal space so that a series of jointly used and managed zones can be established between the participants (Ciolek, 1983). If he is alone, that is, not in the presence of others, he cannot make territorial claims in the shape of personal bubbles because the entire space surrounding him is at his disposal. However, there exists some form of *body buffer zone*[8] or personal space left around the body that keeps him apart from the surrounding people and objects (Ibid.: 70).

Interaction space, or the space between two or more interacting people, what Goffman labelled use space (1971), implies a choice in the part of the participants. It is an area "deliberately created and maintained" (Ciolek, 1983: 65). When it comes to measuring the distance involving the space surrounding a single individual's body, Sommer recommends the use of the term "personal space" as described above. When the measurement involves "the space between two or more interacting individuals, then interaction distance should be used" (Sommer, 2002: 656). With this classification, personal space is a "mental construction, similar to body image in its subjectivity and individual centeredness" while interaction distance is an "objective concept, measured in terms of distances between two or more people" (Ibid.: 656). To measure the interaction space, and following Sommers recommendation, this thesis uses Hall's "*zone system*" (Ibid.: 656).

3.3.1.2 Proxemics or the how of distance-setting

Hall (1959, 1966) viewed interpersonal distance as a "type of nonverbal communication that conveys information about the nature of participants relationship both to themselves and to observers" (Sommer, 2002: 648). He introduced the term Proxemics for "the study of spatial relationships in the course of face-to-face interactions" (Ciolek, 1983:71; Hall, 1959, 1966).

Hall researched man's use of space "the space that he maintains between himself and his fellows and which he builds around him in his home and office" (Hall 1966: introduction X). In doing so, he expected to increase the experience of this relationship and make a contribution to "help reintroduce man to himself" (Ibid: introduction X). The central theme of his research is the "social and personal space and man's perception of it" (Ibid.: 1). Proxemics is the term coined to define" the interrelated observations and theories of man's use of space as a specialized elaboration of culture" (Ibid.: 1).

Hall claims that culture is key to the communication process, that people from different cultures inhabit different sensory worlds, and so experience is perceived through a filter that is cultural and the same input will have different outputs in different cultural realities (Ibid.: 2). In spite of this, human behaviour is rooted in biology and physiology. He acknowledges the influence the work of ethologists - "the scientists who study animal behaviour and the relation of organisms to their environment" (Ibid.: 4) - had on his work. He sees the relationship between man and culture as one in which "both *man and his environment participate in molding each other* (italics in the original)" (Ibid.: 4). Man creates the physical world in which he lives which in return creates different types of people.

The field of Proxemics focuses its attention on the spatial behaviour of man: "Proxemics deals with architecture, furniture, and the use of space […] (and is) concerned with the setting. […] Proxemics seeks to determine the how of distance-setting" (Hall 1968:84). Hall considered distance-setting dynamics to be a "culturally elaborated form of communication" (Ibid.: 94). His studies centred on the "micro-space in interpersonal encounters", in the study of the "empty space" around individuals, the "boundaries " and the "individual and personal distance" (Ibid.: 83), to mention a few names he considered instead of Proxemics to define his ideas. He believed that taking "a look at the various manifestations of territoriality […] should help provide both a foundation and a perspective to be used in considering more complex human elaborations of space"(Ibid.: 84). His take on the study of the man-environment relationship leaned towards the understanding of distance-setting dynamics in order to know more about people's use of space. For Hall "(T)he boundaries of the self extend beyond the body" (1966: 11). The distance setting process occurs mostly outside awareness and it is therefore difficult to grasp.

Hall's research was driven by questions such as: "How many distances do human beings have and how do we distinguish them? What is it that differentiates one distance from the other?" (1966:107). He developed a "Chart Showing Interplay Of The Distant & Immediate Receptors In Proxemic Perception" (Hall 1968.:92-93) that specified in feet, what he termed "an Informal Distance classification", where four types of distances are described: intimate, personal, social or consultive and public (each with a close and a far phase). These are described as a series of invisible bubbles that surround the individual or a set of irregularly shaped balloons (Hall 1966: 10, 12). It describes how individuals use distance as a mechanism in interacting with other individuals. Hall affirms this taxonomy describes "the building blocks that should be used in designing our homes and our cities" (Hall 1966,: 93).

3.3.1.2.2 Informal Distance Classification

Intimate Distance

Intimate distance is characterised by the fact that "the (physical) presence of the other person is unmistakable and may at times be overwhelming" (Hall 1966: 110).

Close Phase – Love-making distance

In its close phase, intimate distance "[…] is the distance of love-making and wrestling, comforting and protecting. Physical contact or the high possibility of physical involvement is uppermost in the awareness of both persons" (Ibid.: 110)

Far Phase – 6-18 inches/0.15-0.45 metres bubble

In its far phase, intimate distance is still very close to the body and its use in public is not considered proper. Hands can reach and grasp extremities.

Personal Distance

Personal distance is a concept that originates from ethology. Hediger (1961) used it originally to define the distance that animals maintain between themselves and their fellows. This distance acts as a protective sphere surrounding the organism. It might be thought of as a small, invisible, variously-shaped bubble that individuals maintain between themselves and others.

Close Phase – 1.5-2.5 feet/0.46-0.76 metres zone

In its close phase, one can hold or grasp the other person and where people stand in relation to each other signals their relationship and/or how they feel toward each other. This is still a very socially and physically close distance.

Far Phase – 2.5-4 feet/0.76-1.22 metres zone

Personal distance in its far phase implies "keeping someone at arm's length" (Ibid.: 113). Imagine two people in conversation; this far phase extends from the point where one person can just touch the other, to the point where two people can touch fingers if they extend both arms. Hall says, "This is the limit of physical domination […] Beyond it, a person cannot easily "get his hands on" someone else" (Ibid: 113). At this distance, matters of personal interest and involvement can be discussed. Voice levels are moderate.

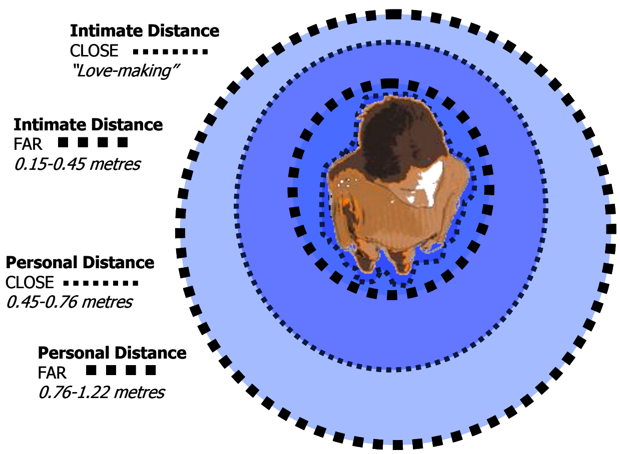


Figure 3.2 Illustration of Intimate and Personal Distance for an individual, as protective spheres and invisible boundaries.

Social Distance

At this distance, individuals do not touch or expect to touch or be touched by another person. Voice levels are normal and "conversations can be overheard at a distance of up to twenty feet" (Ibid.: 114)

Close Phase –4-7 feet/1.22-2.13 metres zone

This is the distance Hall identifies with conducting business. He affirms that people who work together tend to use the close stage of social distance.

Far Phase – 7-12 feet/2.13-3.66 metres zone

But he also notes that conversations and business conducted at this distance have a more formal character than those taking place in the close phase. That is the main reason to chose the close phase of Personal distance for this study, because is focused on informal face-to-face interaction which happens at a closer distance than more formal interaction exchanges.

Hall points out that desks in the offices of senior managers are large enough to hold people at this distance and that in standard-size desks, the chair opposite is 2.5 or 3 metres away from the person behind the desk. At this distance people can also continue to work in the presence of another person or people, ignoring their presence without being rude

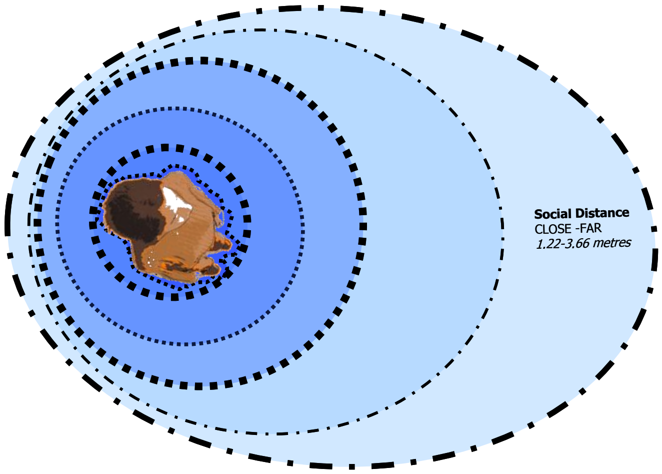


Figure 3.3 Illustration of Social Distance for an individual, as protective sphere and invisible boundary containing Personal and Intimate spaces.

Public Distance

At this distance, individuals are well outside the "circle of involvement" (Ibid.: 116). It is the distance associated with public occasions as well as public figures. Its Close Phase measures between 12-25 feet/3.66-7.62 metres and the Far Phase measures between 25 feet/7.62 metres or more.

3.3.1.2.3 E.T. Hall's legacy

Hall's wider legacy lies in Proxemics being "by far the most well developed of the theories of human spatial behaviour" (Aiello, 1987: 392) and initiating, together with Sommer, the development of human spatial behaviour research (Ibid.: 391). In particular for this thesis his zone system is used to measure the interaction distance between individuals engaged in informal face-to-face conversations. Hall provides clues as to what types of activities, transactions and relationships are associated with each distance. The Personal distance zone is the most relevant concept for this thesis. 0.75 cm becomes the distance that is used to measure interaction. When one person's personal space boundary is overlapped by another's, there is a strong possibility of interaction.

Hall highlights the importance of understanding spatial needs and the use of those zones individuals make for architecture. By imagining people surrounded by "a series of invisible bubbles which have measurable dimensions" (Ibid: 121) architects can design buildings and dwellings that provide for those needs. Lack of space and lack of solo time have been proven to provoke stressful situations that affect human behaviour. Hall also believed that this classification could lead to better understanding of basic personality types, specifically of situated personalities (Goffman would say socially situated). Situational personalities are "associated with responses to intimate, personal, social and public transactions" (Hall 1966: 109). Examples are those people who never develop the public phase of their personalities and make very poor speakers; others have trouble with the intimate and personal zones and cannot tolerate being close to others.

Personal distance and the impact Hall's ideas have had and can still have (Sommer, 2002) for design and architecture, understanding of human spatial behaviour and even of personality types are issues that are explored further in chapter 9.

3.3.1.2.4 Limitations

Hall's Proxemics theory has been mainly criticised because of the well researched fact that distances vary with "individual, interpersonal, and situational factors" (Ciolek, 1983: 70), a fact that he himself acknowledged: "the measured distances vary somewhat with differences in personality and environmental factors" (Hall, 1966: 110). The classification described above reflects body boundary perceptions of a specific slice of the North American population in the 1960's. Hall's research points out the difficulty of setting distances that work across different cultures and groups: "Interpersonal distance is a constellation of sensory inputs that is coded in a particular way"(Ibid.: 94). Using any classification like personal space or Hall's distance zones assumes that reactions to distance are not continuous when in reality experiences occur more gradually (Aiello, 1987). Hall's classification is based on observations and interviews, and therefore bound to be criticised, for he quantified distance based on qualitative information. Nonetheless, subsequent research has proven him fairly accurate (see Altman and Vinsel's review of research findings relating to Hall's spatial zones, Altman and Vinsel, 1977), and his ideas both in the realm of the physical (Van Bommel and Caminada, 1982; Raynham, 2004) as well as the digital world are still going strong (Sommer, 2002).

3.3.1.2.5 Gaps

Hall intimates at the end of *The Hidden Dimension* that the quantitative measurement of "people's (sensorial) involvement ratios" (Hall 1966: 177), of how groups of people get involved with each other could answer questions of ideal density, community size and integration with the environment. The measurement of the interaction distance applied to office buildings, could be a ratio of interaction activity. Having a measure for it could answer questions such as the ideal percentage of interaction, ideal size of interacting groups, categories of interactants and even input into the design process to find out how space can be used to achieve all this. At the time of writing his book, Hall affirmed that there were no techniques to compute this. This thesis aims to take this measurement forward using some modern technologies.

3.3.1.3 Interpersonal boundary regulation

As Hall initiated human spatial behaviour research with his proxemic framework, so others also developed models to explain the relationships among spatial behaviour and other behavioural variables. One of those variables is privacy and "the ability to regulate social contact" (Sundstrom, 1987: 759).

Privacy has gathered momentum as a topic of organisational interest for similar reasons that interaction has. With the advent of the knowledge economy and the increasing complexity and dynamism of knowledge work, knowledge workers require continuous learning and autonomy and flexibility in their ways of working. Learning has increased the need for concentration and hence privacy. Also, individuals and groups are most effective when they can adequately control their privacy (Werner et al., 1992). Whereas face-to-face interaction is one of the key means workers have to keep the flow of information moving, solitary time is the mean to transform that information into something of value, for example, knowledge.

But are privacy and solitary time the same thing? Theorists have usually defined privacy in one of three ways: "as a retreat from people, as management of information, or as regulation of interpersonal interaction" (Sundstrom, 1987: 759). This last definition derives from the belief that people make every effort to maintain an optimum level of interaction with others. Privacy exists as long as an individual or a group have "selective control over access" by other people (Altman, 1975, 1976). When control fails, situations of crowding (too much interaction) or isolation (too little), occur with consequences over behaviour – social withdrawal and depression, to name a few (Evans et al., 1996).

Hall's work focused on the how of distance setting and his research suggested that individuals are surrounded by invisible boundaries that, if trespassed upon, can provoke stress, withdrawal or defence. Altman's work takes this a step further and focuses on "how people *close* themselves off from others and how they avoid being overly exposed and vulnerable [...] (for) it is important, psychologically, for people to be able to avoid contact with others" (italics in the original, Altman et al., 1981: 112, 115). Part of his work and that of his associates can be interpreted as dealing with "interpersonal boundary processes and, more specifically, with the openness and closedness of people to one another" (Ibid.: 129), an "important feature of social interaction" (Ibid.: 130). It is this part of their work that is most relevant to this thesis.

Altman exemplifies this by saying that: "(I)f a person desires a lot of interaction and only gets a little, he feels lonely, isolated or cut off. And if he actually receives more interaction than he originally desired, he feels intruded upon, crowded or overloaded. However what is too much, too little, or ideal shifts with time and circumstances" (Altman, 1975: 25). Here is reflected the notion that privacy is not a "keep out or let in process; it involves a synthesis of being in contact with others and being out of contact with others" (Ibid.: 23). There is a privacy continuum where individuals fluctuate between the desire to withdraw or not interact and the desire to be in contact with others. Individuals and groups are motivated to be both open and closed to interaction and external factors affect this desire – social pressures, societal norms and demands and various environmental factors. There is no ideal state, interaction or non interaction is subject to various circumstances. Also, this relationship varies thorough time exhibiting "patterns or cycles of stability and change [...] over the course of a relationship" (Altman et al., 1981: 131). So privacy can also mean less contact with others, which manifests in a variety of behaviours such as spending time alone. He suggests that "concepts of openness-closedness can be operationally defined by a variety of behavioural indicators" (Ibid.: 128), and that when people experience too much or too little interaction, they attempt to correct the situation through "privacy-regulation mechanisms", comprising verbal and non-verbal behaviours (Altman, 1975). Non-verbal behaviours include the "use of the physical environment to regulate contact with others" (Sundstrom, 1987: 759). This aspect will be dealt with in detail in section 3.3.2 in this chapter.

Altman and his colleagues, in a later review of his early work, assume that interaction functions in accordance with two dialectical processes, openness and closedness and stability and change. They also assume that the poles of the two oppositions are equally important, that they function together as a unified system and that the interplay of these processes is not aimed at achieving an ideal state (Altman et al., 1981: 127). Interaction and privacy are therefore two measurements of human spatial behaviour in organisations. Opposites lend meaning and definition to one another (Altman et al., 1981, Werner et al., 1992). In this context, solitary time is the measurable manifestation of privacy, specifically of those periods of time when individuals close themselves to interaction with others. This is a behaviour that can be voluntary or involuntary, desired or not, dynamic and context dependent, for it is influenced by its spatial and temporal circumstances. Solitary time is key in processing the pieces of information gathered through physical interaction, assimilating them and transforming them into knowledge valuable to the individual and the organisation.

3.3.1.3.1 Altman's legacy and limitations

Altman and collaborators' model is significant in that it helps understanding the complexities of interpersonal interaction in three aspects. First, their definition of privacy as a dynamic phenomenon that varies through time and that can be measured through observable behaviours, such as interaction or solitary time, feeds directly into the methodology developed in this thesis. Second, their work acknowledges the existence of forces that influence behaviour, the openness and closedness of relationships and their stability and change. These are organisational forces, in the form of policies and rules, and design forces, or spatial features that either hinder (barriers i.e. walls, screens), or enable (i.e. open spaces, long visual lines), the "interplay of approach and avoidance forces" (Altman et al., 1981:130) affecting those relationships. Last, their work also points out that the concepts of timing and matching can facilitate the analysis of the social relationship as a unit of study. He and his collaborators developed empirically testable hypotheses about the development and management of interpersonal relationships. They focused on the "amplitude and frequency characteristics of openness-closedness cycles" but did not address "the dimensions of regularity or relative duration [...] because of the complexity associated with these dimensions of stability-change" (Altman et al., 1981: 142). The value of their work resides in them suggesting new directions of research to advance the quantitative understanding of social behaviour (Altman et al., 1981).

The main limitation of this body of work is the difficulty of its measuring, it does not predict behaviour and it has not been fully tested and therefore able to be refuted. In addition, their work points at the individual as a unit of study, not to dyadic or multiparty relationships and doesn't provide "the *interactive* quality of social relationships, where the unit of study is the relationship or the joint behaviour of participants" (Altman et al., 1981:151). One of the reasons given for this neglect is "the difficulty of studying interactive processes over time" (Ibid.: 151).

3.3.1.3.2 Gaps

Altman and his collaborators provide further depth into the study of interpersonal boundary processes, specifically the openness and closedness of social relationships and their stability and change through time. Their work points towards the importance of understanding the fluctuations of those dynamic patterns of behaviour and how the regulation of interpersonal distance ebbs and flows through time. Their work, though pointing out these issues, does not provide specific measurements. They provide empirical hypotheses but do not have the tools to test them and one criticism is that "statistical analyses were less of a concern to them" (Werner and Baxter, 1994: 332).

3.3.1.4 Next steps

All this evidence points to the relevance that the concepts of personal space, interaction distance, privacy and solitary time, and the existence of spatial and temporal forces have on regulating face-to-face interaction. While Goffman shows what to measure in face-to-face interaction (1959, 1966, 1971, 1974, 1983), Sommer (1959, 1969, 2002) and Hall (1959, 1966, 1968) point towards exactly where the measurements start and Hall (1966) specifically provides the distance to measure interaction. The work of Altman and his collaborators (Altman, 1975, 1976; Altman et al., 1981; Werner et al., 1992) closes the search for operational concepts by providing the measurable behaviour that this thesis needs to develop the method: solitary time.

In this thesis, interaction distance and solitary time are treated as two possible physical behaviours out of many used by individuals to establish the desired level of interaction. For interaction to happen it is necessary that two or more people share a micro-environment of between 0.45 to 0.75 centimetres (personal distance in its close phase). It is in this space, where two or more people are in close physical distance, where personal conversations take place (Hall, 1966; Schein, 2004), and, it is argued in this thesis, informal interaction. Also, in order for individuals to internalise information, a degree of privacy and some solitary time away from others, is desirable.

However, in order to build a method to study interaction dynamics in the workplace, the identification of factors that influence the process is needed. The work of Hall (1959, 1966, 1968) Sommer (1959, 1969, 2002) and (Altman et al., 1981) suggests that the physical environment plays an important role in the management of interaction. Goffman (1959, 1966, 1971, 1974, 1983) suggests that all face-to-face interaction is circumscribed in time and space, while Altman's research (Altman, 1975, 1976; Altman et al., 1981; Werner et al., 1992) affirms that spending time on one's own appears as critical to the learning and knowledge creation process. Therefore, further questions spring to mind:

- How long do two or more people need to share an interaction space for it to be considered an interaction?
- How long does informal face-to-face interaction, typically last for?
- And what are the effects of the physical environment in the interaction and solo work dynamics?

In the next two sections a review of research is conducted with the aim of answering these questions and identifying a number of spatial attributes and temporal dimensions that affect face-to-face interaction dynamics in the workplace. The evidence provided materialises in the hypotheses list presented in the next chapter to be tested through the case study fieldwork.

3.3.2 Human spatial behaviour in the workplace

The study of human spatial behaviour derives from a number of disciplines. The earliest work in this area was based primarily in the work of ethologists and ornithologists who focused on "territorial behaviour and distance regulation of animals and birds" (Aiello, 1987: 390). Their research heavily influenced early work focusing on human spatial behaviour - Hall and Sommer and many others after them. This early research also maintained a broad view on space use and the environment in which humans live, making it a key variable in the understanding of human spatial behaviour. A parallel development began in the 1960s which focused less on space as the single variable of interest to understanding spatial behaviour, and more as one of a number of components that people use to "establish a desired involvement level for interaction" (Ibid.: 390).

Researchers from other disciplines – sociology, ecology, geography, psychiatry and architecture, added an "interdisciplinary richness and diversity to this budding research domain" (Ibid.: 390). The diversity of disciplines led to an abundance of terms of the spatial behaviour concept. Sommer suggests the use of personal space and interaction distance as more appropriate concepts for human spatial behaviour (2002).

The study of personal space and interaction distance, and of the interplay of environmental forces that hinder or enable face-to-face interaction behaviour, underlie most research in this area. In this section, the review has focused on spatial behaviour research with an emphasis on the spatial factors that influence the way people interact physically in the workplace. The focal point is the office work environment because the office is "the primary focus of research for understanding the workplace" (McCoy, 2002: 443). Space syntax literature deserves a subsection in this field for its unique take on revealing and quantifying the hidden "social logic of space" (Hillier and Hanson, 1984).

3.3.2.1 Behaviour in work environments

The complex nature of organisations was remarked upon in Chapter 2. The physical workplace is one component of that complex system of relationships (Hatch, 1997; McCoy, 2002). This section focuses on research dealing with the role of the physical environment within the organisation, its relationship with workers' behaviour and, specifically interaction processes and the way in which the environment is incorporated (Sundstrom, 1987; McCoy, 2002). The links between the physical space, solitary work and interactive work are reviewed, specifically "the features and attributes of space that support or inhibit both the ability to concentrate on key tasks as well as the ability to engage with others" (Heerwagen et al., 2004: 512).

The specific work environment of interest for this thesis is the office. The term office here refers to "settings where the primary activities comprise the handling of information and the making of plans and decisions. Examples include facilities devoted to accounting, administration, banking, finance, insurance, publishing, or research" (Sundstrom, 1987: 733). The office is a place where individuals are required to read, think and talk to others; where groups are required to communicate and collaborate. It is a place provided by the organisation to support these activities and their contribution to the organisational strategic goals (McCoy, 2002). The term physical environment refers here to "properties of buildings that contain offices [...] particularly their interior conditions and arrangements" (Sundstrom, 1987: 733) and to how these properties provide "both functional opportunities and multiple levels of meaningful interaction and feedback for the people who work in them" (McCoy, 2002: 443). The office is a component of the organisation and represents a resource for achieving organisational goals. Ideally, says Sundstrom, the environment within an organisation should be congruent with its other tangible and intangible resources (Sundstrom, 1987; Heerwagen et al., 2004; Rashid et al., 2006). Research conducted in this area generally aims to evaluate how successful specific features and properties of the work environment are in relation to individuals and groups performance (generally understood as efficiency), and satisfaction (generally understood as a general evaluation of the job to be performed (McCoy, 2002).

In the last 20 years, the traditional concept of the office has evolved and alternatives to the more hierarchical structures, results of the introduction of new technologies and of new economies, have developed. Office work is knowledge work and employees are seen as recipients/sources of both their own individual and organisational knowledge (Nonaka, 1994; Davenport and Prusak, 1998; Nonaka and Toyama, 2007; Becker and Sims, 2001; Brill et al., 2001; McCoy, 2002, Rashid et al. 2006; Fayard and Weeks, 2007). Nonaka suggests that managers need to build, maintain and connect shared contexts – physical, virtual or mental spaces – in motion (the concept of *ba*) and promote interactions in such spaces, as knowledge is created through interactions (Nonaka 1994; Nonaka and Takeuchi 1995; Nonaka and Toyama 2007).

Knowledge work is characterised by being a highly cognitive and a highly social process. Workers need to spend time alone "to think and develop ideas, drawing on their own memory, insight and analytical skills" (Heerwagen et al., 2004: 511). They also need to externalise and share those ideas in order for them to become useful for the organisation (McCoy, 2002). Consequently, knowledge work involves both solitary work and conversation and interaction allowing thoughts to be accessible to others. In this context, alternative offices such as virtual offices, home offices, hotelling, hot desking, non-territorial offices, etc, have been developed in order to reflect new organisational needs and to provide spaces for new ways of working. The newly created patterns of work require new conceptualisations of spatial organisation and allocation that facilitate and accommodate change. New workplaces must find ways of anticipating, managing and responding to change (McCoy, 2002).

It is worth pointing out that empirical research on offices is uneven (Sundstrom, 1987; McCoy, 2002). In particular, regarding the topic of interaction, research has been conducted in a limited range of work settings – scientific research and development, software engineering and creative professions, usually on brief interaction (Heerwagen et al. 2004), or under the umbrella of communication, that is, "focusing upon the convenience and quality of face-to-face conversations" (Sundstrom, 1987: 756). The challenge for organisations and designers, both researchers and practitioners, is twofold: on one hand, it is rooted in using space to balance the specific organisational need for interaction and solo work; on the other, the challenge rests on understanding those specific needs, looking at interaction and privacy as means to aid particular kinds of work processes and tasks (Heerwagen et al., 2004, 2006).

3.3.2.2 Key interaction and solo work behaviours

When focusing on the physical environment and the features that that can potentially enable these processes, current research approaches try for the most part to link spatial features with behavioural outcomes. But at the level of interpersonal processes it is very difficult to separate outcomes and processes. Interaction and privacy are outcome and process at the same time. The regulation of interaction - privacy processes, is inextricably related to the regulation of physical proximity, or to be very precise of immediacy and to the choices in communication channels, face-to-face or other means (Sundstrom, 1987). For small groups of people, their interface with the features and properties of the physical work environment may be evaluated as levels of interaction and levels of privacy (McCoy, 2002; Heerwagen et al., 2004, 2006).[9]

Literature suggests that, in general, people at work first, spend most of their interactive time face-to-face (Reder and Schawb, 1990; Perlow, 1999; Brill et al., 2001; Heerwagen et al., 2004); second, most of these face-to-face interactions are spontaneous rather than planned (Backhouse and Drew, 1992; Penn et al., 1999; Rashid et al., 2006), and lastly, proximity is essential to facilitate the chance to engage in face-to-face conversation (Allen 1977; Kraut et al., 1990).

For solitary work to take place is essential to have the time, space and tools to do it and be effective. Some tasks can be done in the presence of others but other tasks, requiring focused attention, suffer from distraction and interruptions which affects individuals' performance (Perlow, 1999, Heerwagen et al. 2004, 2006). Distractions can be visual as well as auditory but do not imply necessarily work stoppage. Interruptions on the other hand are events that cause work to stop. At work, most interruptions are due to people stopping by one's workspace (Reder and Schawb, 1990; Perlow, 1995, 1999; Backhouse and Drew, 1992; Penn et al., 1999; Rashid et al. 2006). To have control over ambient conditions, be able to find places for concentration, have access to necessary tools and have autonomy regarding space and time are key methods to reduce the ill effects of distractions and interruptions (McCoy, 2002; Heerwagen et al. 2006).

Next, evidence is presented regarding spatial features that support or inhibit engagement with others in conversation. Following this, evidence will be provided about the spatial attributes that sustain or hinder the ability to do solitary work.

3.3.2.2.1 Spatial features affecting interaction in the workplace

BOSTI reported that one workplace feature with strong effects on performance and satisfaction is the ability to support spontaneous interactions (Brill et al., 2001). Offering a variety of places in which people can come face-to-face without pre-planning it is important in that not having such areas may not develop the social abilities apparently linked to performance (McCoy, 2000 quoted in McCoy, 2002). The features and properties of the workplace that provide opportunities to interact relate to visual access, circulation patterns and office layout, proximity to others, and location of natural meeting places.

Circulation, layout and visibility

This particular set of features affects the chance of interaction in as much as, when combined, they influence movement, co-presence and perceived availability of others for recruitment into a conversation. Sight is one of the distance receptors (the other is hearing) which affects the perceptions of space and the relations of individuals in space (Hall, 1966: 37). Vision enables individuals to identify others and their states, gather information about them and navigate through space (Ibid.: 61). Baker studied visibility and interaction in small groups and proved empirically that visibility has an independent effect on participation, although he pointed out that visibility interacts in complex ways with other variables such as leadership and personal style (1984). McCoy in her review of workplace literature concludes that "(v)iews of co-workers in the workplace may be necessary for efficient, effective team performance, thus enhancing performance" (2002: 453), although she does not differentiate between "seeing" and "being seen".

This relates to the concept of recruiting into interaction, or identifying available co-workers by the fact that they have left their workstations and are moving through the office (Backhouse and Drew, 1992). What individuals see influences how they act and contribute to the identification of potential opportunities for interaction. Workplaces should be designed around strategic positions and their actual and potential lines of sight, for these influence people's ability to recruit or be recruited, which in turn affects the chance to engage in spontaneous interactions (Backhouse and Drew, 1992; Heerwagen et al., 2004; Penn et al., 1999; Rashid et al., 2006). Interestingly, no views may also provide opportunities for uninterrupted conversation (McCoy, 2002). In open plan offices which are supposed to encourage face-to-face interaction through visual accessibility, evidence is scarce and contradictory. Increases in physical interaction haven't been consistent (Sundstrom, 1987; Rashid et al., 2006). The relationship is not straightforward and circulation and layout mediate the effect of open plan layouts on the occurrence of interaction (Oseland and Bartlett, 1999). Circulation systems that funnel movement instead of dispersing it have been suggested to increase the chance of interaction. So have layouts that enable physical access from multiple areas. Space syntax research has been particularly prolific in these analyses. A summary of their contribution to this topic is presented in the next section.

Proximity

Physical constraints to interaction, such as lack of proximity which makes difficult to find or talk to the right people are quoted as one of the main "drags on knowledge"(Prusak and Weiss, 2007: 40), for physical proximity is said to be one of the main two factors that make knowledge transfer possible (Leonard 2007:61). A common hypothesis that underlies research in these interrelated issues is that placing people in close proximity facilitates face-to-face conversations. It is argued that if it is convenient for them, people will interact more physically (Oseland and Bartlett, 1999).

Physical accessibility, "proximity or the lack of barriers between them" (Sundstrom, 1987: 757), is a factor both in the choice of medium of communication – i.e. face-to-face conversation, and in the choice of the recipient of the communication. Formal communication does not seem to be affected by physical proximity of workspaces within the same building, suggesting that people go as far as needed for formal meetings. For work related contact people chooses face-to-face conversation more often when their work spaces are physically close.

Proximity of workspaces has been found to be related to informal communication. T. J. Allen established long ago that the probability of communication and relations among individuals and groups decreases with distance, and quantified the phenomenon that it declines to an asymptotic level within the first 50 metres of separation. Comparisons between industries show very little difference in communication behaviour (Allen, 1977, 2007). Kraut and his colleagues found that "Work place conversations are, in general, quite local events, usually involving people who are physically in close proximity to each other" (Kraut et al., 1990:41). In their study of informal communication occurring in buildings of an industrial research laboratory and a state university, where the aim of the study was to examine the characteristics of a sample of face-to-face interactions among members of these two organisations, they also found out that "52% of all conversations involved people located within the same corridor, and 87% of them took place among people who shared the same floor in a building." Physical proximity helps informal face-to-face interaction by "allowing appropriate people to encounter each other frequently, by supporting visual channels to induce and assess readiness for communication, and by supporting highly interactive conversation" (Ibid.: 41). Physical proximity is being taken seriously by firms, building knowledge campuses and redesigning offices to overcome or reduce physical constraints to interaction and encourage knowledge sharing either intentionally or serendipitously (Prusak and Weiss, 2007; Fayard and Weeks, 2007).

Gathering places

The existence of gathering places outside individual work spaces, areas "where people's paths cross during routine activities" (Sundstrom, 1987: 758) have been suggested as important for interaction. Natural meeting areas such as the coffee area and copy room, are supposed to promote interaction, but there is little evidence to support this. Now, if these facilities happen to be located on busy paths there is a link to interaction. This might suggest that the pathway is more important than the destination itself (Heerwagen et al., 2004), an aspect that is studied by space syntax and summarised in section 3.3.2.4 below.

Fayard and Weeks throw some light on this issue as well. They conducted a qualitative study in the affordances photocopier rooms and water cooler areas have for interaction behaviour (Fayard and Weeks, 2007). They follow Gibson in believing that "The affordances of an object or environment are the possibilities for action called forth by it to a perceiving subject" (Ibid.: 609). Their findings suggest that these spaces "afford informal interaction to the extent that they bring people into contact with each other (propinquity), allow people to control the boundaries of their conversation (privacy), and provide legitimate rationalizations for people to stay and talk to each other (social designation)" (Ibid.: 625).

Fayard and Weeks point out though that using physical characteristics alone such as centrality or enclosure to analyse behaviour, is simplistic, and that social norms also intervene in the regulation of interaction and privacy. It is only when the social characteristics of a space are included in the analysis that the behavioural affordances of a space are understood. These attractors, when open and highly trafficked, lack the physical elements of privacy, and so fail to afford informal interaction "despite their propinquity benefits and despite their explicit and official designation" (Ibid.: 626). This research in turn links to observations made by numerous authors pointing out the strong mediating role that the organisation structure has on the potential for its physical structure to enable interaction (Heerwagen et al., 2004, 2006; Rashid et al., 2006; Shpuza, 2006).

To summarise, key spatial features that promote awareness and interaction need good visual access into surrounding spaces to aid eye contact, visually open workstations, central entrances and pathways that increase the probability of encounters, central open stairways and layouts and design that promotes efficient wayfinding (Sundstrom, 1987; McCoy, 2002; Heerwagen et al., 2004). This translates at the level of the room layout to the seating arrangements and furniture, and at the building layout level to the inter-work-space proximity, type and degree of enclosure of workspaces, accessibility, location and visual features of gathering places (Sundstrom, 1987; Heerwagen et al., 2004, 2006).

3.3.2.2.2 Spatial features that support regulation of privacy in the workplace

BOSTI reported that it is not only the ability to support spontaneous interactions that has a strong effect on performance and satisfaction; the ability to do solo work is also key to those processes (Brill et al., 2001). Key spatial factors that support solitary work include "high degree of enclosure, low density [...] and distance from high-circulation areas" (Heerwagen et al., 2004: 523).

Privacy at work, understood as regulation of interpersonal interaction, connotes retreat from observation or audition or from unwanted interruption, distraction or from its cause: interaction[10]. Distractions have been identified as one of the two major causes of productivity loss in offices (Oseland, 1999; Haynes, 2007). One of the aspects that links privacy, interaction and satisfaction with the physical environment, is the potential that the workplace has of enabling people to control interaction. In open plan offices the lack of enclosure makes privacy a major problem. Most studies relating enclosure and privacy are limited in that they rarely assess the enclosure of individual work spaces which usually varies between rooms. Instead, most report average perceptions of the entire office staff. Studies that have measured it have found enclosure consistently associated with privacy, but this connection varies with the individual's job. Physical enclosure has been identified as a necessary factor to satisfy different needs for people in different jobs. Speech privacy appears to be particularly important to managers (Sundstrom, 1987).

Interesting results correlating individuals' conscious choices for privacy over the plans of multi-bed hospital wards are related to two measures of spatial location obtained through space syntax analytical tool Depthmap (Turner, 2001, 2004): integration and control of visual fields (Alalouch and Aspinall, 2007). The invisible properties of physical environments affect preferred privacy location choices. This point is discussed in further detail in 3.3.2.4. Low levels of density allow people to distance themselves from disruptive noise and also to choose the interaction distance they need in particular situations and particular spaces. Two well researched findings in the area of interpersonal relations and spatial behaviour have been proven to underlie this process. Firstly, p*eople interact at a closer distance with people they like and know better*: "...people use least space with friends and others they like than with acquaintances and others about whom they feel slightly positive to neutral, and they use less space with individuals in this intermediate affect category than with strangers and others they dislike" (Aiello, 1987: 459). What is more, people need more space when stressed, insulted, angered "or placed in a competitive or formal setting" (Ibid.: 459), and wish to distance themselves physically from those that cause stress, anxiety or make them uncomfortable. Secondly, w*hen people move from larger, more open spaces to smaller, confining spaces they adapt by distancing themselves from others*: "...people maintain closer distances when in the center (rather than the corner) of a room; in rooms with higher (rather than lower) ceilings; in narrow (rather than square) rooms; in larger (rather than smaller) rooms; and outside (rather than inside)" (Ibid.: 459). High circulation areas are good places to locate common use areas where people have the chance to meet and engage in conversation.

These are not good places, though, to locate a private office (Oseland and Bartlett, 1999; Rashid et al., 2006). The volume of traffic will be far too distractive (Backhouse and Drew, 1992).

Spatial features affecting regulation of behaviour

Level of analysis	Operational Terms	Key Social Processes	Key Spatial Features and Attributes	Key Behavioural Outcomes
Interpersonal Relationships	Personal Space Interaction Distance Privacy	Regulation of Interaction	Circulation Layout Visibility Proximity Gathering places	Awareness Face-to-face interaction Spontaneous brief interactions ***Privacy loss*** ***Distractions*** ***Interruptions*** ***Reduced solo time*** ***Potential stress***
		Regulation of Solo Work	Enclosure Low density Distance from high-circulation areas	Increased attention capacity Reduced stress Improved time on task ***Reduced awareness*** ***Reduced potential for interaction***

Table 3.2 Summary of spatial features that affect interaction and solo work

3.3.2.3 Limitations

Without exhausting potential criticism of this body of research, limitations come from a variety of points. Firstly, the balance needed to accommodate both interaction and solo work in the office environment is a challenge to managers and designers, researchers and practitioners alike. Secondly, the organisational structure has a strong mediation on the potential role of space and its measurable effects on interaction and privacy behaviour. Thirdly, a fairly simplistic approach to the role space plays in the development of these relationships is commonplace in the literature. Finally, most of the literature focuses on the observable physical properties of space more than on its invisible or structural properties.

The spatial features that promote interaction, such as good visual access, visually open workstations and proximity of workers can be potentially disruptive to privacy, or the ability to do solo work. This is a consequence of the loss of visual and acoustic privacy, potential interruptions and distractions, noise from others' talking and reduced time available to spend on individual tasks (Heerwagen et al., 2004). But while physical features of a workplace that tend to increase privacy tend also to decrease proximity and vice versa, a degree of both is necessary for specific types of face-to-face interaction - those that require some degree of confidentiality. "Propinquity and privacy do not cause informal interaction, but they do more than enable it: they encourage it, they may even obligate it" (Fayard and Weeks, 2007: 609). This obligation though, can be resisted by the individuals.

The physical setting is chosen by individuals taking into account the type of encounter they intend to have, the degree of informality of the interaction and the number of people involved. People might not see space as it is defined by the organisation – i.e. flexible, ancillary, desk etc – but by the affordances it provides for hosting the encounter (Fayard and Weeks, 2007). These affordances can be created through design but need to be reinforced – legitimised – by the company through policies and culture. Nonaka and his collaborators have pointed out that creating physical spaces for interaction is a potential strategy to encourage it although this is inefficient if executed in isolation (Nonaka 1994, Nonaka and Takeuchi 1995, Nonaka and Toyama 2007). The managerial model used by the organisation weighs more in the outcome behaviour than the spatial features of layouts (Shpuza, 2006). The key lies in building congruent relationships between space, the organisational model and the behaviour desired. A work environment that allows the individuals to control sufficiently the features that enable them to access and regulate their interaction needs, will result in better satisfaction and improved performance. The challenge is on designing workplaces that deliver flexibility, adaptability and responsiveness to workers' needs and anticipate, manage and respond to change (McCoy, 2002).

The reviewed evidence proves that assumptions concerning human behaviour, notably lacking in empirical verification, are commonplace in the office design literature. The reason for this is the complexity of the relationship of interaction processes and spatial variables, that when reduced to a few quantitative categories, does not reflect the causes or meaning of the behaviour observed. These analyses are arguably incomplete, for the social meaning of the space (how is it socially labelled) and the norms that apply within it (be those rules of interruption (Fayard and Weeks, 2007), recruiting (Backhouse and Drew, 1992) or talk (Webber, 1993), will affect the privacy of a space, and therefore the qualitative use of it (Fayard and Weeks, 2007), and need to be studied and included in the research.

Given that most of the literature has focused on the observable physical properties of space, there is also a need to look to its invisible properties. Space syntax research has approached space from a social point of view looking into the structural properties of layouts and how they work towards enabling coawareness, copresence and encounter in the built environment.

3.3.2.4 The Social Logic of Space

The built space, from a social point of view, can be understood as a "field of structured copresence, coawareness, and encounter" (Peponis and Wineman, 2002: 271). The built space organises the way in which behaviours, activities and people come together or remain apart. Space is either a *connector* that generates relationships of integration, segregation, differentiation or a *boundary* that creates relations of "enclosure, contiguity, containment, subdivision, accessibility and visibility" (Ibid.: 271). Space has a "social logic" in that this pattern of connections and boundaries affects the structuring of social relationships and therefore becomes intelligible through their spatial form (Ibid.: 271). This is the theory that underlies *space syntax*[11] research.

Two basic theorems illustrate two contrasting ways in which space works socially: the theorem of generative spaces and the theorem of reproductive spaces.

Generative spaces

This theorem suggests that spaces with more direct universal accessibility have a higher probability that the space will be used for movement, be it a building (through its circulation layout) or an urban area (through streets). This further suggests that:

a) distribution of movement is a function of spatial configuration;

b) a virtual community arises as a by-product of movement, based on patterns of copresence and coawareness – i.e. as daily commuters, (Hillier, 1989) ;

c) spatial systems are economies where particular space uses locate according to passing movement.

Space has, therefore, a generative function: movement and social relationships arise from spatial configuration itself.

Reproductive spaces

This theorem addresses the underlying spatial relationships that define building types. A list of components of a building – typically labelled by activity, social rule or function, is not a building. "Buildings set component spaces into particular patterns of relationships" (Peponis and Wineman, 2002: 272) but the precise pattern varies from design to design. Some of those spaces are always more directly accessible than others. For example, the reception is usually more accessible than the server room. Space has a reproductive function in that it contributes to the reproduction of social structures.

The identification of generative and reproductive functions of space demonstrates that "it is possible to identify certain underlying structures of space that are linked to observable patterns of behaviour and that these patterns, in turn, create social function, whether generative [...] or reproductive" (Ibid.: 272). In the space syntax literature, these functions of space are treated either as opposed to one another or as complementary, depending on subject matter or point of view. Peponis and Wineman remark that these two kind of functions are rooted upon a property they define as direct accessibility, which implies that "diverse social effects share the same spatial foundation" (Ibid.: 272). Measures of accessibility are functions of a) the number of direction changes made; b) the number of boundaries crossed c) the number of spaces traversed. "Access to space implies access to people, resources, or information" (Ibid.: 285).

The effects of the spatial layout of buildings on bringing people together or setting them apart has been found to be very close to the organisational formal structure. Layout and formal organisation act together to regulate interaction in different and sometimes opposed ways. Space syntax research suggests that organisations with strong control cultures are associated with "strong" program buildings, where layout is used to control movement, interaction and encounter in a prescribed manner. In contrast, organisations characterised by dynamism, flexibility of working forms and looser hierarchical structures, are linked to "weak" program buildings, the layout is less restrictive and contributes to the organisational modus operandi by sustaining encounter, copresence and awareness (Hillier, Hanson and Peponis, 1984; Peponis, 1985; Hillier and Penn, 1991; Penn et al., 1999).

Regarding the more objective aspects of spatial layout that have been linked to interaction, strong correlations have been found between interaction and integration of the layout where more integrated office segments – i.e. floors, autonomous wings, are more interactive (Grajewski, 1993; Serrato and Wineman, 1999). Visible coawareness and copresence have been found to be the base in which particular patterns of encounter and interaction may develop in the workplace (Rashid et al., 2006). They suggest that visible copresence outweighs movement and that an office with more visible copresence "may result in more face-to-face interaction regardless of movement" (Ibid.: 842). Spatial depth (having space to withdraw from unwanted contact with others), has been found to be related to the attenuation of the effects of density on psychological distress

(Evans et al., 1996). Spatial segregation and few connections of space with the main circulation system appear to be related to increased privacy (Rashid and Zimring, 2003; Rashid et al., 2006). Along these lines, research conducted in hospital wards reveals that integration and control of visual fields is correlated to individuals' choices of privacy locations. At ward level, people choose wards that score low on integration values and high on control values; for bed location within the ward, choices reveal preferences for privacy for locations with lower integration and lower control of visual fields (Alalouch and Aspinall, 2007).

Although the syntactic analysis of buildings appears more fragmented than those of the urban environment, some clear ideas emerge from it (Peponis and Wienman, 2002). First, there is a correlation between integration and movement patterns that seem to be constrained by the building program, reflecting the organisational modus operandi. Second, coawareness and copresence as a function of visibility are the base on which particular patterns of encounter and interaction may develop. Third, there is a fundamental distinction between organisations that inhabit space generatively, so as to sustain unprogrammed patterns of interaction, associated with "weak" program buildings, and those that do it in a restricted manner, associated with "strong" building programs. Finally and most importantly is the idea that "buildings should be treated as mechanisms for creating spatial interfaces among categories of people, activities, behaviours and functions" (Peponis and Wineman, 2002: 282). The idea of the building as interface is key to help understand how a building program (the purpose of the organisation to inhabit space), translates into building layout.

3.3.2.5 Gaps

In studies of interaction in the workplace, the focus has been, generally, on what spatial features – be they visible or invisible - affect human behaviour. Leaving aside specific methodological limitations that current methods exhibit, as discussed in 3.3.4, the overarching gap that cuts across approaches is the lack of a finer grain analysis of behaviour, of behavioural data that is rich in location information. If the possibility of augmenting the analysis of behaviour occurring in specific spatial points (100.000 observation instead of 20), and if the chance to quantitatively measure personal space and interaction distance comes up, would that affect our understanding of human spatial behaviour in the workplace?

It has been argued that the physical environment can enter into people's choices of interaction, and the occupants of an environment may adjust their settings and their behaviours to regulate their encounters with each other. Accurate behavioural location information can help to understand individual and group preferences for face-to-face encounters. The possibility of fine grain quantitative behaviour measuring has immediate impact on calculating the effect design and organisational policies and interventions have on the location of workers interaction dynamics. Understanding where face-to-face interaction and solitary work takes place is important to understanding the adequacy of the type of space and the characteristics of those particular environments. The road to identification and the comparability of the degree to which specific spatial features enhance or inhibit interaction can potentially be unblocked.

3.3.3 Dimensions of time in face-to-face interaction

In organisations, time is a fundamental aspect of the order of work life: "The perception and experience of time are among the most central aspects of how any group functions" (Schein, 2004: 151). Different assumptions of time lead typically to communication and relationship problems. It has been argued that time is critical for organisations for it is invisible, taken for granted and difficult to talk about. Time dynamics associated with interpersonal relationships are particularly difficult to measure comprehensively (Schein, 2004).

Whereas in the previous section the review of evidence focused on the spatial features that inhibit or support interaction and solo work, the approach in this section is somewhat different. The focus is on understanding what the key temporal variables in organisational research are and which ones specifically affect interaction and solo work dynamics. Firstly, a brief discussion on the temporal dimensions in work environments is introduced, focusing on the view of time this thesis adopts, conversely, that time is one of the aspects individuals and groups need to manage to achieve the desired level of interaction/privacy. Secondly, given that informal face-to-face interaction plays a key role in the knowledge process, a characterisation of its temporal nature based on available evidence is presented. Finally, limitations to current research and methods to study time and interaction in the workplace are outlined and gaps identified.

3.3.3.1 Time dimensions in work environments

Time is not a "unidimensional, clear construct" (Schein, 2004: 152) and it has been analysed from a number of perspectives. Ancona and collaborators reviewed key literature on time and organisations in four critical areas of knowledge within the field of organisations: organisation theory, sociology, social psychology, and anthropology. They define time as "a nonspatial continuum in which events occur in apparently irreversible succession from the past through the present to the future" (Ancona et al., 2001: 513). They classified the temporal variables in organisations as related to three sets of variables. The first set concentrates on the nature of the time continuum and captures different conceptions of time in organisations. Two subcategories were found: a) Types of time, which include different ways of describing the time continuum: clock time, cyclical time, event time (predictable and unpredictable) and life cycle; b) Socially constructed time, which refers to "how different social groups create or culturally construct different types of time that become shared meanings about the continuum" (Ibid.: 515), a typical example is the construction of time as clock time in the industrialised Western societies. The second set of variables focuses on activities and how they map to the time continuum. Examples of these variables include duration, rate, frequency, scheduling, cycles, rhythms, allocations of activities in relation to time, to other activities and the activities of other actors. Many of them involve "an explicit and deliberate creation of order – an engineering of the activities on the continuum" (Ibid.: 515), see table 3.3 for details. The last set of variables considers the actors engaged in the activities mentioned above and explores how different actors relate with the continuum of time[12]. Ancona and collaborators found two subcategories: a) temporal perception variables such as time passing and time dragging (McGrath and Kelly, 1986), "which capture how actors perceive the continuum" and b) temporal personality variables such as temporal orientation and temporal style, "which capture how actors act with regard to the continuum" (Ancona et al., 2001: 518). They acknowledge that these three categories are interrelated and some variables span categories as well. McGrath and Kelly illustrate the complexity of temporal arrangements in organisations by explaining that most organisations today carry the dominant cultural conception of time as "scarce, linear, divisible, homogeneous" (McGrath and Kelly, 1986: 12). This gives rise to certain key temporal problems: "temporal ambiguity, temporally conflicting demands, and the inherent scarcity of time" (Ibid.: 12). Organisations respond to this by using different strategies, namely "scheduling, synchronization, and allocation", which in turn give rise to problems for the individual and how they react to the strategies and that is connected to the temporal aspects of "role ambiguity, role conflict, and role overload" (Ibid.: 13). The three categories and multiple variables interconnect; the organisational conception of time affects the mapping of activities to time and both, in return, affect how actors react to time.

Temporal Variables in Organisations

Category	Subcategory	Sample Variables
Conceptions of time	Types of time	Linear time, uniform time, cyclical time, subjective time, event time
	Socially constructed time	Work organization (nine-to-five workdays, work time and family time), celebrations (Passover and/or Easter), time as a renewing cycle, time as linear continuity
Mapping activities to time	Single activity mapping (a)	Scheduling, rate of completion, duration
	Repeated activity mapping (aa)	Cycle, rhythm, frequency, interval
	Single activity transformation	Life cycles, midpoint transitions, jolts, mapping (aa') interrupts, deadline behavior
	Multiple activity mapping (ab)	Relocation of activities, allocation of time, ordering, synchronization
	Comparison and meshing of activity	Entrainment, patterning, temporal symmetry maps (ab) versus (aa)
Actors relating to time	Temporal perception	Experience of time, time passing, time dragging, experience of duration, experience of novelty
	Temporal personality	Temporal orientation, temporal style

Table 3.3 Temporal variables in organisations based on Ancona et al., 2001.

3.3.3.2 Temporal variables of interpersonal processes in the workplace

Although highlighting the interrelated nature of the three categories, Ancona et al. suggest that it is the second category of temporal variables, duration, frequency, pace and rhythm, that "directly links the work of organizations, through activities, to the temporal continuum" (Ancona et al., 2001: 524). Altman and his collaborators work on interpersonal relations, views time as one aspect of many that need to be managed in order to achieve a balance between levels of desired interaction and privacy at work (Altman, 1975; Altman et al., 1981; Werner and Haggard, 1985; Werner et al., 1992; Werner and Baxter, 1994). Their work emphasises the role of temporal processes in social relationships. They are conscious of the importance of regularity and duration as key dimensions "in the development and management of interpersonal relationships" (Altman et al., 1981: 142). They highlight the theoretical existence – theoretical for they have not proved it - of cycles and variations of states of interaction and non interaction (openness and closedness) within a day and throughout the day and remark on how little is known about such "short-term and long-term units of analysis" (Ibid.: 145). They describe hypothetical cases of timing and mistiming (temporal synchrony and nonsynchrony of interaction), and of matching and mismatching (when interactions differ in their degree of substantive matching, or "subject matter of interaction" (Ibid.: 153). There can be situations where people are in synchrony of interaction (timed), but not in the content of their exchange. The interesting point here, they say, is how the exploration of these states can lead to an understanding of the development and management of relationships.

Following Ancona and collaborators' framework, it is argued that interaction and solitary work are two types of activities sharing the same temporal parameters (i.e. duration, frequency, pace), that, depending on the organisation, might have different "temporal zones", with different characteristics, different cultures, and different conceptions of time. Temporal coordination mechanisms are needed to reduce conflict across activities and temporal zones (McGrath and Kelly, 1986; Ancona et al., 2001).

Perlow further advances these arguments stating that "to understand the use of time among workers, when their work requires that they spend some portion of their time uninterrupted and some portion interacting, one needs to focus on the workers' interdependent work patterns and not just on any one worker's independent use of time" (Perlow, 1999: 58). She further argues that "to assess the effectiveness of time use, the impact individuals have on each other needs to be considered" (Ibid.: 59). In the organisational context interaction and non interaction activities therefore require that individuals' efforts are sequenced and interrelated efficiently. For the study of interaction and solo work dynamics in the workplace, it seems appropriate to focus on the analysis of their shared temporal parameters (rates, duration, cycles etc.) taking into account the organisation's conception of time and the workers reactions to the organisational temporal strategies.

3.3.3.3 Temporal behaviour in the knowledge workplace

The existing literature on time use contributes to a partial understanding of both how and why individuals do and should spend their time at work (Perlow, 1999). There has been even less research of time related behaviour at the interpersonal level in the office environment (Perry et al., 1995).

Time budget studies have examined how people allocate their time across daily activities. Research on what particular types of workers do focus mainly on individuals' use of time at work. Other researchers more interested in explaining the existence of patterns in the ways people use their time have used the concept of entrainment (borrowed from biology), to define the process by which one cyclic rhythm becomes captured by and set to oscillate with another, arguing that socially constructed temporal rhythms dictate individuals' behaviour (McGrath and Kelly, 1986). Both scientific management and, of late, time management, further prescribe the ways people should use their time at work (Perlow, 1999). There is very little research that focuses on measuring the amount of time workers spend interacting with others and even less that link this activity to the need to spend some portion of their time doing uninterrupted solitary work. It is a question of understanding how the use of time by some individuals might affect other's use of their temporal resources. In the context of the knowledge organisation where workers are required both to interact and to work on their own, the study of the interdependence of these dynamics appears essential to "assess the effectiveness of time use" (Ibid.: 59).

A review of research that has explored face-to-face interaction and solitary work, although not necessarily at the same time or from the same perspective, throws some light over the temporal characteristics of interpersonal behaviour in the workplace. Some of these studies have focused on understanding the role of communication in multitasking and cooperative behaviour (Reder and Schawb, 1990; Su et al., 2007; Su and Mark, 2008); informal communication as a coordination mechanism in organisational climates characterised by their uncertainty (Kraut et al., 1990); understanding its nature in organisations in order to design collaborative communication technology (Kraut et al., 1990; Whittaker et al., 1994), understanding time usage in software development (Perry et al., 1995), to assess the effectiveness of time use in organisations (Perlow, 1999), in the context of understanding office productivity (Becker and Sims, 2001) and exploring the relationship of interaction and identity in a corporate campus (Becker et al., 2003).

Reder and Schwab, in their ethnographic study of the temporal structure of solitary work and interaction through different media (face-to-face, telephone, other), found out that in terms of their distribution by role, it was senior managers that spent more time interacting face-to-face (63%) and much less time doing solitary work (16%), than any of the other groups. In contrast, sales development spent around a 25% in face-to-face interaction and 50% of their time in solo work, the marketing group doing a 35% - 40% distribution. But in terms of volume of activities, the number of interaction events and solo work events these groups are observed performing, the distribution is different. Senior managers were observed as having roughly 25% of face-to-face interactions and 25% of solo work events. Sales development and marketing workgroups had a 20%/40% distribution (Reder and Schawb, 1990). These data suggest that, for example, senior managers have more or less the same number of interactions and solo work episodes, but spend much more time talking to people than concentrating on solo tasks. The other two groups seem to have a more balanced relationship between their observed interactions and solo events and the time spent performing each activity. Reder and Schwab provide specific data to prove this point, suggesting that the role influences the duration of units of activity, being "the mean duration for solitary work activities more than 9 minutes for sales development and 7 minutes for the marketing groups, [...] (and) less than 4 minutes for the Senior Management Group" (Ibid.: 308). They do not provide data on how many minutes on average these workgroups spent in face-to-face interaction.

Kraut, Fish, Root and Chalfonte, in their ethnographic study on informal communication in organisations portray informal face-to-face interaction as brief, unplanned and frequent (Kraut et al., 1990). Part of their study explores aspects of the temporal structure of informal face-to-face interactions. They categorised these by the degree of preplanning and discovered that of the total of conversations identified 12% were scheduled, 36% were intended (when one person goes to visit another), 21% were opportunistic (taking advantage of a chance encounter to talk to someone that the initiator of the conversation wanted to talk to at some point) and 31% were spontaneous (no planning at all). They assumed that scheduled meetings are formal, therefore 88% of all the conversations observed are informal. The duration of the conversations was found to be influenced by the degree of preplanning. Generally, the more spontaneous the conversation the briefer it tended to be. The median duration of a scheduled conversation was about 30 minutes while intended, opportunistic and spontaneous interactions have each a median of under 10 minutes (Ibid.: 81).

Whittaker, Frohlich and Daly-Jones, in their ethnographic study of informal workplace communication, confirm Kraut and collaborators findings on the nature of informal interaction in the workplace, highlighting its context dependence (Whittaker et al., 1994). They studied mobile professionals' informal communications and discovered that this amounted to 31% of their work time. This figure is composed of a "large number of brief, unplanned, dyadic (two people) interactions" and they remark that for the subjects "extended, arranged, multiparty (more than two people) interactions" were highly unusual (Ibid.: 133). For these 31% interactions, the mean duration is 1.89 and the mean frequency is 5.98. A large 92.86% is reported to be unscheduled and an 83.32% dyadic or between two individuals. In their analysis they distinguish between conversations held in one's office (14%) with a mean duration of 2.37 minutes and a mean frequency of 11.57 minutes, and conversations held outside of one's office (17%), with a mean duration of 1.38 minutes and a mean frequency of 12.38 minutes. Regarding the reported dyadic nature of informal interaction they further report that 88% of interactions "were terminated by a third party joining an existing conversation" (Ibid.: 135).

A further analysis into the duration of informal face-to-face interaction in one's own office discovered that 50% of conversations last less than 38 seconds. They also discovered that more frequent interactants had briefer conversations, for frequency, they argue, "affects the interactants familiarity with the subject material of each other" (Ibid.: 134). The duration of conversations between infrequent interactants lasts 219 seconds on average.

Whittaker et al. noted that location influences the duration of informal face-to-face interaction outside of one's own office. The majority of those "roaming" conversations happened in another's person office (67%) with a mean duration of 1.94 minutes; 15% took place in public areas with a mean duration of 1.06 minutes; 17% happened on the move with a mean duration of 0.82 minutes. They also report a few longer interactions (1%) that took place in dedicated meeting rooms with a mean of 13.13 minutes (Ibid.: 134). Becker and Sims in a study of office productivity report that duration is affected by the location of the interaction. Interactions are briefer, about 2 minutes, in pods and bullpens[13] than in closed offices, where it lasts around five minutes. The more open the environment, the more frequent the communication and the shorter the duration (Becker and Sims, 2001). In a later study of interaction in a corporate campus they state that the number of people involved in the encounter also influences its duration. They report that meetings with 3 or more people lasted longer than two person meetings (16% >60 minutes vs. 2%>60 minutes) (Becker et al., 2003).

Perry, Staudenmayer and Votta, Jr., in their ethnographic study on time usage in software product development, found out that engineers spent 35 minutes a day in informal – unplanned and unanticipated - face-to-face interactions. The median duration of interaction observed is around 3 minutes (Perry et al., 1995).

Perlow analysed duration by focusing on sequences of activities in a software company (Perlow, 1999). Whereas just over 30% of engineers' time was spent on interactive activities, close to 60% of their time was spent alone. She discovered that 70% of the uninterrupted blocks of time reported by the engineers were one hour or less in length and of those, 60% were half an hour or less in length. This close examination of the sequences of individual and interactive activities revealed that a large proportion of the time spent uninterrupted on individual activities was spent in "very short blocks of time, sandwiched between interactive activities" (Ibid.: 64).

She also found frequency and the degree of spontaneity to be related. 95% of those interactive activities occurred spontaneously. The spontaneity of the interactions fragmented the day's work and left the engineers with no control over their schedule. The engineers considered these interactions useful for the most part but they were also considered as interruptions and as disruptive to their work. Perlow's research indicates that "interactions structure individuals' use of time by fragmenting uninterrupted, individual blocks of time" and that "the same interactive activities produce both positive benefits associated with interacting and negative consequences associated with interruptions" (Ibid: 75).

Su, Mark and Sutton in an ethnographic study of the types of contexts coexisting in the workplace that lead people to form multiple forms of social interaction, found that the informants averaged about a quarter of their day (1 hr. 52 min.) interacting informally face-to-face. The average time for each interaction was quite brief (1 min. 56 sec. on average). The results confirmed their expectation that people rapidly switch interactions. Face to face interactions make up a significant percentage of interactions (28.40%) compared to e-mail, instant messaging, paper, phone, meeting and CM (content management system) (Su et al., 2007).

Su and Mark, in a further analysis of communication chains – "the occurrence of interaction in quick successions" (Su and Mark, 2008: 83), categorised interactions as face-to-face, meeting, phone, instant messaging and email; solitary work consisted of "working alone" in front of the computer, using "specialty tools" and paper (Ibid.: 85). Their data on face-to-face interaction is aggregated in "communication acts" by context, and they report an average of "2hr. 18 min. on communication acts per day" - the majority of which were done with others inside the company boundaries. Regarding solitary work they report that "(i)nformants averaged about 3 hr. on solitary work per day" (Ibid.: 86). Their work also suggests – through predictions of probabilities using Markov chains[14] - that communication chains started via face-to-face interaction are "the most probable" and the shortest – in terms of average number of links, after instant messaging initiated chains. E-mail and phone-initiated chains are longer, meaning that they involve more links to complete (Ibid.: 87)[15]. Chain length is therefore not the same as Chain duration – the sum of link durations in a chain. In fact, the temporally shortest chains are those initiated by instant messaging, followed by e-mail initiated ones, and being the communications initiated via face-to-face and phone media the ones that take more time to complete. Longer chain duration (sum of link duration in a communication chain) they found to lead to more stress, "possibly leaving less time for solitary work", as well as longer link duration (median value in seconds) which they suggest implies that "longer communication acts lead to more stress" (Ibid.: 89). They triangulated these quantitative findings with interview analysis to better understand multitasking. Their analysis reveals that "informants tried to use their limited work time efficiently for communication" (Ibid.: 90), even if the choice of media takes up more time – i.e. face-to-face, because it is perceived as worthwhile. People will most probably choose face-to-face interaction to start a communication, because it's more straightforward to get work done – it involves less media switches, and although it takes longer than, for example, e-mail, to finish a task, it is perceived as socially valuable. So, communication started via face-to-face is the most probable type to occur. It takes less links or switches of media to end and together with phone conversations is the choice of communication that leads to longer interactions. At the level of perceptions, face-to-face interactions are valued for social reasons.

Su and Mark conclude by suggesting that for some people it might be more efficient to interact with others after a period of solitary work in order to get the information they need to continue with solo work. Also, interruptions tend to provoke longer chain length and more organisational switches (the number of switches made between work contexts) which in turn are associated with job strain. They sum up saying that "most of the work people do is alignment with different people – this is very difficult work and causes stress; however, the freedom to navigate between different people in different organisational contexts with choice of media may allow one to cope better with this stress"(Ibid.: 90).

3.3.3.4 Summary of temporal behaviour characteristics

Ethnographic findings suggest that the nature of informal face-to-face interactions is" brief, unplanned, and frequent"(Kraut et al., 1990; Whittaker et al., 1994), and that workers have small blocks of uninterrupted time, punctuated by frequent, brief conversations. In fact, informal face-to-face interaction "seems to consist of one long intermittent conversation consisting of multiple unplanned fragments" (Whittaker et al., 1994: 136).

Temporal behaviour in the knowledge workplace portrays individuals as continuously attempting to manage or alter the trade-off between solo time and interaction time. They are portrayed as making an effort to achieve the desired level of uninterrupted periods of time needed to get work done and being available for interaction with other workers. This process is dynamic, changes through time, is mostly out of their control, and its measure needs an approach that can cope with very small units of time.

The opportunistic nature of informal interaction is deemed to be the reason why most of this type of conversations are not multiparty, because the chances of two people simultaneously being in the same place are greater than for three (Whittaker et al., 1994). The degree of opportunism appears to be related to the degree of pre-arrangement or formality of the conversation and to the duration and location of the event, but these issues have not been tested jointly yet.

Amount and duration of each activity is linked to role and type of work. Interaction duration is linked to degree of informality, volume of participants and location of the encounter. Interaction frequency is linked to degree of spontaneity of encounter. But the small samples and short periods of time most of these studies span, together with the problem of observing multiparty interactions influence undoubtedly these conclusions.

Keeping the structure outlined in the previous section when summarising spatial features affecting interaction and solo work, here is a summary of the temporal dimensions affecting the regulation of those behaviours in the workplace. See table 3.4.

Temporal conditions affecting regulation of behaviour

Level of analysis	Operational Terms	Key Social Processes	Key Temporal Variables	Key Behavioural Outcomes
Interpersonal Relationships	Personal Space Interaction Distance Privacy	Regulation of Interaction Time	Amount of Time Duration Frequency Sequences	Brief Opportunistic Dyadic Volume of Participants Degree of Informality Location Preferences ***Interaction Overload*** ***Time Famine*** ***Ineffective Time Management***
		Regulation of Solo Time	Amount of Time Duration Frequency Sequences	Block of Uninterrupted Time Location Solo Activities Location Preferences ***Interruptions*** ***Location Interruptions***

Table 3.4 Summary of Temporal conditions affecting interaction and solo time in organisations[16].

3.3.3.5 Limitations

McGrath and Kelly affirm that "many interesting aspects of behaviour can be seen only by looking at patterns of behaviour over relatively micro level units of time" (McGrath and Kelly, 1986: 103). But whereas they advocate the study of temporal factors to understand social processes, provide useful terms and provocative hypotheses, there is a clear gap between the ideas proposed and the practicality of measuring "the pervasiveness of cyclic processes in human interaction" (Ibid.: 171).

As the findings on the basic temporal properties of face-to-face interaction and solitary time show, this small number of studies are first, usually focused on an overarching topic such as communication or time use, more than on the temporal characteristics of these activities; second, it stands out that very little research has been done specifically on the temporal dimensions of solitary work; and third, all studies are conducted on small samples for a brief and limited period of time.

Although all of the methods used in those studies look into the structure and use of time in the workplace at a micro level (most down to the second) there are limitations regarding the methods used – direct and participant observations, shadowing, interviews, tracking logs and video and audio recording of activities. Firstly, they all are painstaking in terms of cognitive attention for the observers; secondly, all of them are enormously time consuming and, therefore expensive (Bakeman and Gottman, 1986). Finally, and most importantly, none of them provide a full coverage of work time down to the second, throughout the whole working day, the week, the month or the year, mainly because of the combination of the previous two reasons.

A number of reasons for the dearth of research in this area is that researchers lack a basic understanding of how to gather time-related information at the micro-level (Perry et al., 1995), the lack of a framework to analyse time in organisations (Ancona et al., 2001), and the difficulty to systematically observe and record a continuous stream of behaviour using manual methods (Bakeman and Gottman, 1986).

3.3.3.6 Gaps

The intricate choreography of work in organisations requires effective coordination and effective use of time (Kraut et al., 1990; Perlow, 1999). Current methods do not seem able to present a comprehensive picture of the cyclic processes that manage the flow and changes in informal face-to-face interaction and solo time dynamics. In the face of the qualitative and quantitative data presented, there seems to be a clear need for two things.

Firstly, focus on physical interaction processes per se, separating them from other related issues. Secondly, the development of new tools that can study the pervasive nature of interaction processes, easing the cognitive burden[17] associated to the study of these processes by human observers, and that can successfully tackle the challenges of volume of participants engaged on interaction activities, time consumption and pervasive time coverage.

3.3.4 Current measurement of temporal and spatial behaviour: strategies, techniques and limitations

It is noteworthy that all the research reviewed in this chapter examined the phenomenon of face-to-face interaction using similar strategies differing in the specific background subject matter and in their theoretical underpinnings.

A brief overview of the methods used by the authors referred to along this chapter shows that, for example, Goffman used naturalistic observations in his study of face-to-face interaction (Goffman, 1959, 1966, 1971, 1974, 1983); that Hall determined the how of distance setting by employing "observation, experiment, interviews (structured and unstructured), analysis of the English lexicon, and the study of space as it is recreated in literature and in art" (Hall, 1962: 88); that the methods used by Perlow involved participant observation, interviews, self-assessed tracking longs and debriefing interviews, shadowing and performance data released by the company subject of study (Perlow, 1999); that to study duration Kraut and collaborators used self-reports of communication and shadowing (Kraut et al., 1990.:27); and that Rashid and his colleagues used a combination of observational methods and space syntax analysis to understand face-to-face interaction in the workplace (Rashid et al., 2006).

Regarding the subject matters, firstly, the study of interpersonal distance reflects the interest in understanding both how the variation of distance affects other behaviours and how different factors affect the distance setting mechanisms. Secondly, the study of interaction in the workplace focuses on studying how the physical environment is relevant to individual and group satisfaction and organisational performance, and thirdly, studies of time in organisations aim to uncover the patterns of underlying activities or events, such as interaction, in relation to time.

3.3.4.1 Spatial behaviour measurement: personal space and interaction distance

In the measure of spatial behaviour, the objective has been to identify the "determinants of interpersonal distance" (Sommer, 2002: 651). Interpersonal or interaction distance has been treated either as an independent variable – subject to quantitative manipulation, in studies that focus on the relationship between increased/decreased physical proximity and other interaction behaviours, or as a dependent variable, where the effects on distance is measured in relation to other variables, i.e. environmental, personality or cultural (Aiello, 1987; Sommer, 2002).

Human spatial behaviour understood as personal distance, interpersonal distance or interaction distance (Aiello, 1987; Sommer, 2002) has been measured using mainly three strategies: projective or simulation studies, quasi-projective or laboratory methods, interactional or field/naturalistic methods (Aiello, 1987). Sommer reduces those to two: field studies – "anonymous individuals in natural settings are unaware that their behaviour is being recorded", and simulations – "the participants are aware that they are being observed or tested, although the particular variables of interest to the researcher may not be specified" (Sommer, 2002: 651).

3.3.4.2 Research strategies in workplace settings

Strategies of research on work environments include both qualitative and quantitative methods. Quantitative methods tend to be used in "measurements and evaluation of thermal conditions, light, sound, and contents of indoor air quality on performance" ; qualitative methods are employed to "capture a broad range of activities and responses that might require more complex explanations" (McCoy, 2002: 444), such as spatial preferences or activity patterns.

Quantitative methods include field experiments – "direct interventions in work environments, coupled with systematic measurements to assess their impact" (Sundstrom, 1987: 737), and laboratory experiments – which "allow researchers to establish causal connections between aspects of the physical environment and participants' responses in artificial settings" (Ibid.: 737).

Qualitative methods include observations, interviews, shadowing techniques, tracking logs, audio and video recording and activity or behaviour mapping as tools to understand behaviour of people at work. Surveys and questionnaires as the "systematic asking of questions" (Sundstrom, 1987: 737) are used to determine "user preference or attitude" (McCoy, 2002: 444).

Increasingly common is the combination of multiple methods of investigation used to understand the complex relationships between people's behaviour, the physical environment and the organisational structure (McCoy, 2002). An interesting take on the study of these relationships is that of space syntax. Space syntax methods provide a flexible framework for describing layouts at different scales and from different points of view. A range of measurements and tools can be used to study and analyse visual fields, lines of movement, patterns of connectivity, choice of paths, etc. (Peponis and Wineman, 2002). Some of these techniques are summarised in the next chapter.

3.3.4.3 Limitations

In order to achieve the generalisation of findings in spatial behaviour/interaction distance, the method that would allow it would be field studies using "valid and unobtrusive observations of distances maintained between identifiable interacting (or copresent) individuals in their naturalistic setting" (Aiello, 1987: 409). These ideal circumstances are not found in most studies as on the one hand, there is usually some degree of awareness on the part of the subjects towards the study in question when a process that individuals are unaware of becomes suddenly very salient and, on the other, "it would be virtually impossible to study this domain of spatial behaviour using interactional (field/naturalistic) measures of interpersonal distance exclusively" (Ibid.: 411). Current methods cannot capture this process in a unobtrusive, real time and continuous way.

Regarding empirical research conducted in the workplace, although many studies are conducted in real environments the main limitation is related to the reported fact that these studies are usually "isolated studies of specific problems, often with minimal ties to theory" (Sundstrom, 1987: 736), and more often than not are unclear about original conditions, procedures and participant recruitment, suffering from narrow empirical basis (McCoy, 2002).

Space syntax techniques, on the other hand, have been criticised for their limitations arising from the use of topological measures for dealing with urban layouts (Ratti, 2004). In particular, inside buildings, because activity and space use are regulated by different forces, their analyses haven't been able to predict movement and behaviour as well as in urban environments (Peponis and Wineman, 2002). But some of their techniques can help identify spatial variables, i.e. visual fields, which can be "controlled and quantified in ways that are richer and more rigorous than is often the case with behavioural research associated with the design of the environment" (Ibid.: 276).

It is interesting how time in particular is a dimension that has usually gone unmeasured and to ahve discovered a paradox in the approach to time as a dimension in both interaction distance and workplace research. For whereastime has usually gone unmeasruedin what Ancona and collaborators denominate the set of variables focused on mapping activities to the time continuum (duration, sequence and so on), time is ubiquitous in the methods employed by all studies. There are temporal features and temporal considerations in all studies reviewed.

Regarding the main limitations found, studies typically cover too little time failing to show the accumulation effect of a given set of circumstances over a long period of time, say a year. Also, in the study of interaction distance, time has not been considered a key variable to see how affects interpersonal distance, if it changes through time, or how different temporal variables affect it, and how. With regard to the workplace, most studies have a very limited duration and avoid – or are unable to get access to, the study of change through time, focusing mainly on short-term phenomena (Sundstrom, 1987: 737), and not tracking the influence of the interventions or solutions over time (McCoy, 2002). Furthermore, most studies make strong assumptions about how interaction processes unfold in time. Longer does not necessarily mean more or better interaction (McGrath and Kelly, 1986). The most damaging temporal problem of all, they say, is "the lack of fit between (our) methods and (our) theories in regard to the temporal intervals necessary for causal processes to unfold" (Ibid.: 14). Without specifying how long intervals between two activities last for plus the added problem of arbitrary choice of time intervals, current methods do not allow to know if what is measured is the effect "at its peak, its ebb, or somewhere in between" (Ibid.: 14). Finally, current methods seem to analyse gatherings of not more than two people. Most studies focus on the individual or on dyads (two people gatherings), mostly out of convenience, for it simplifies the observational task (Ciolek and Kendon, 1980).

3.3.4.4 Gaps

The complexity of investigating with current observational methods **actual behaviour**, in **real time and space, continously through time**, involving **multiparty gatherings,** are the main gaps identified through the literature review. There is a need to study real environments in real time where people behave without obstruction and without limits to the spatial and temporal information needed to do it. In this thesis is proposed that interaction behaviour can be studied with the use of new technologies that have the potential to capture information in very fine detail, ease the manual burden associated with current methods and including these variables in the measurement (Perry et al., 1995).

3.4. Summary of Chapter 3

The review of evidence presented in this chapter, has led to the identification of the set of theoretical assumptions that rule physical interaction processes: personal space, interaction distance and the regulation of privacy and the spatial features and temporal variables that affect and characterise the regulation of these dynamics. The form of these basic rules will vary from group to group, from organisation to organisation, but the fact that those rules exist, that the combination has not been studied before and that they can be measured using new technologies opens the door for the development of a new method to study interaction. An effort to identify specific variables with the potential to be measured has guided the review of evidence. A summary of the measurements and variables used in this thesis is presented in table 3.5.

So far, the analysis has been conducted by separating the dimensions of time and space, but in reality they always interact in complex ways around the process of interaction. Findings reported in the relationship of spatial and time dimensions with the quality of interpersonal behaviour, leads us to believe that the better people manage their solo time, and the better and more varied their spatial and time related array of privacy mechanisms are, the better their effectiveness at work

(Werner et al.,1992). Research on face-to-face interaction and, in general, on personal relationships, has overlooked the role the physical environment and temporal variables play in the development and management of those relationships. The physical environment "is an integral and essential part of effective intra- and interpersonal functioning" although not the "sole contributor" (Ibid.: 298). Face-to-face interaction takes place in physical space. However, more particularly, when an interaction takes place the occasion itself has characteristic spatial demands, and so different occasions demand different spaces. Encounters also have temporal characteristics that influence their duration and periodicity. Duration and location of these encounters have been proved to be related.

Temporal features are essential to understanding interpersonal relationships (Altman et al., 1981). Temporal dimensions of interaction-solitary time such as pace, rhythm, scale, sequencing, etc are "integral to and lend meaning to interpersonal relations" (Werner et al., 1992: 318). The disruption of temporal qualities can be devastating to interaction dynamics and affect individuals' psychological wellbeing inducing stress, anxiety and time famine (Perlow, 1995, 1999; Mc Grath and Kelly, 1986).

Interaction and privacy are two measurements of human spatial behaviour in organisations. Interaction and solitary time are reverse phenomena; one cannot simultaneously have interaction and time on their own. Literature suggests that workers have conflicting needs for both interaction and to do solo work in order to accomplish their assigned portions of work. Space and time can be used to manage the trade-off. The spatial and temporal characteristics of face-to-face interaction can be measured, but current methods do not offer a comprehensive coverage of those dynamics. The gaps summarised should be seen as an intellectual opportunity to advance knowledge in the study of interaction, not as a detractor of all the research quoted. This thesis is not going to answer all the questions that have been posed; it proposes a method to address some of those aspects under a new light. In Chapter 9, the value and the advantages of the new method proposed in Chapter 4 will be discussed in detail.

What the summary of spatial and temporal conditions suggests is that the major source of problems in organisations – and arguably the cause of productivity loss (Haynes, 2007; Brill et al., 2001) is the mismatch between timing and synchronisation of work interactions, namely interruptions and distractions (Heerwagen et al, 2004) their impact in the effectiveness of the current way of using time (Perlow, 1999), and the mismatch between the workers activities and the work environment provided (Haynes, 2007). The conclusion is that careful observation and analysis of space and time utilisation in the micro structuring of interaction and solitary work would be a productive approach towards understanding the efficiency of workplace design and work time practices. Most of the research discussed throughout this chapter does not treat people, places and time as "inseparable, mutually defining and dynamic" (Werner et al., 1992: 299), although they are. The review portrays a fragmented picture,and this thesis attempts to provide a method to present a holistic and dynamic representation of interpersonal relationships. For people, space and time are integral to the unfolding of interaction-non interaction dynamics in the workplace, and none of their multiple dimensions can be understood except in relation to each other (Ibid.: 300). Interactions cannot be understood outside these multiple frames (Goffman, 1983). Next chapter describes real time, continuous and longitudinal approach aiming to produce a ***fine grain analysis*** of behaviour in the workplace. Potentially, one of the benefits of such an approach is that it might help to understand why some firms are continuously successful, for being interaction a key mechanism in this process and as "novelty emerges in a system based on routines" (Becker et al., 2006) a new and deeper view of it might throw interesting insights into the knowledge generation and the innovation process itself. The method aims to incorporate

Summary of Variables Used in the New Method Development

Measurements	Variables
Interaction/Solitary events	*Personal space, Interaction distance, Privacy regulation*
Spatial features	*Precise location* *Visibility*
Temporal dimensions	*Amount of interaction/solo events* *Duration of events* *Frequency and sequence of events*

Table 3.5 Summary of variables used in the new method development

the measurement of observable behaviours associated with:

- The regulation of the physical boundaries between individuals and the others using the concepts of personal space, interaction distance (Hall, 1959, 1966, 1968; Sommer 1959, 1969, 2002) and privacy regulation (Altman 1975; Altman et al. 1981; Werner et al. 1992);

- The location of interaction and solitary behaviour and the features of the physical environment that help or hinder the regulations of these relationships (Heerwagen et al., 2004, 2006; Rashid et al., 2006)

- Some temporal dimensions of interaction and solitary time; their frequency, duration or scale, pace and recurrence, as well as its volume (McGrath and Kelly, 1986; Perlow, 1995, 1999; Ancona et al., 2001);

The method proposed, while aiming to measure and classify general rules of behaviour in an office environment, implicitly acknowledges the uniqueness of events, although it does not attempt to understand them. Face-to-face interaction dynamics may have a different manifestation in different workplaces and at different times. Therefore, the questions, assumptions and methodologies should adapt to specific contexts. How can a holistic analysis linking people and interaction processes with place over time be conducted? Which advances in new technologies help to bridge the gap between the pervasive nature of human behaviour processes and current methodological limitations? What type of approach can translate the measurements identified into a method to study interaction dynamics?

Key Points

- Physical proximity is an essential precondition for face-to-face interaction.
- Interaction dynamics are defined by their location and their temporal circumstances.
- Personal space is a mental construction, similar to body image in its subjectivity and individual centeredness, while interaction distance is an objective concept, measured in terms of distances between two or more people.
- Personal space is defined as a bubble of 2.5 feet (0.75 cm) radius around the individual. This is the interaction distance used in this thesis.
- Interaction and privacy are two measurements of human spatial behaviour in organisations. In this thesis, solitary time is the measurable manifestation of privacy.
- It can be hypothesised that face-to-face interaction occurs when one person's personal space boundary is overlapped by another's for at least 15 seconds. Solo behaviour occurs when one person's private area is not overlapped by another's.
- Research focused on currently understudied spatial and temporal

dimensions of face-to-face interaction can contribute to better understand work dynamics and therefore improve work structures and workplace designs.

- Knowledge workers spend variable portions of their working days both interacting face-to-face and in solo events.
- Knowledge workers spend an average of 3 minutes in informal face-to-face interactions, most of them lasting less than 38 seconds, with duration varying with location. Solo event duration varies between 4 minutes and an hour.
- Knowledge workers days are characterised by a rapid succession of informal face-to-face interactions and short periods of solitary time.
- Knowledge workers spend more time interacting face-to-face the higher the number of individuals involved.
- Knowledge workers spend more time interacting face-to-face depending on the visual affordances of the location chosen.
- Knowledge workers spend more time in solo events depending on the visual affordances of the location.
- Current methods to study interaction dynamics in organisations are deficient in providing a holistic - real-time, continuous and longitudinal - picture of those.
- The methodological gap identified can be covered with new technologies that provide real time precise location and time data.

Notes

1 Not to confuse the study of small groups with the study of face-to-face interaction. The latter focuses on individuals interactions with other individuals and the rules that regulate their contact (Goffman, 1983). In particular, this thesis deals with the study of certain spatial and temporal rules, involving dyadic (2 people) or multiparty (in this thesis up to 5 individuals). The focus is on informal, repeated and regular but unregulated face-to-face interactions more than on formal or organisationally regulated meetings. Small groups research by contrast, focuses on the psychology, communication within and organisational behaviour of groups that are between 3, and 12 to 20 individuals (Beebe and Masterson, 2006), sharing a common identity and common objectives (Arrow et al., 2000). Although there are similarities between small groups and interactions, the differences are substantial and enough to justify the focus on the interaction order (Goffman, 1983).

2 Simmel was a philosopher for whom sociology was philosophy, “if only with an unequivocally modern mission at the turn of the twentieth century” (Gerhardt 2003:144). He is considered the founding father of the discipline of sociology.

3 Macrosociology addresses large-scale phenomena such as institutional systems, whereas microsociology deals with smaller-scale phenomena such as interpersonal behaviour (Turner and Markovsky, 2007: Reference Online. 15 January 2009 <http://www.sociologyencyclopedia.com/public/book?id=g9781405124331_9781405124331>

4 This idea encouraged the study of how people engaged in interaction enter into and maintain spatial-orientation arrangements and became the study of formation systems (Scheflen & Ashcraft,1976; Kendon, 1977, Ciolek and Kendon 1980).

5 In Relations in Public, 1971, Goffman provides a categorisation of the eight territories of the self: personal space, stalls, use space, turns, sheath, possessional territory, information preserve, and conversational preserve (Goffman, 1971: 28-41). This list is of descriptive character and does not include any form of measurement.

6 The concept of flight distance, when used in human studies, became the basis of invasion studies of personal space (Sommer, 2002).

7 Here lies the main difference with another related concept, that of territory. Territory refers to a fixed geographic location whereas Personal Space does not. The boundaries of territory are marked while those of Personal Space are invisible (Sommer, 2002).

8 Body buffer zone, term introduced by Horowitz, Duff and Stratton (Horowitz et al., 1964) used to refer to the “region of space surrounding an individual which is left free during the period of the person’s transactions with this physical environment” (Ciolek, 1983: 58). Sommer affirms than can be used as a synonym of the term personal space (Sommer, 2002: 648).

9 McCoy says in her review of workplace literature that this relationship can be also evaluated as levels of collaboration and status and identity (McCoy, 2002: 452). Heerwagen and collaborators propose to study collaborative working environments from a framework where effective working together entails both solitary work and interactive work. Brief interactions and collaborations that take the form of short-duration interactions are seen as key social dimensions of collaborative knowledge work (being the other two awareness and collaborations that take the form of long-duration interactions (Heerwagen et al. 2004, 2006).

10 Hall made some thoughtful comments on these issues back in the 1960's: "Crowding per se is neither good nor bad, but rather that overstimulation and disruptions of social relationships as a consequence of overlapping personal distances lead to population collapse. Proper screening can reduce both the disruption and the overstimulation, and permits much higher concentrations of populations. Screening is what we get from rooms, apartments and buildings in cities. Such screening work until several individuals are crowded into one room; then a drastic change occurs. The walls no longer shield and protect, but instead press inward on the inhabitants" (Hall 1966: 175).

11 Space syntax can be defined as a) a set of analytical techniques associated to the theoretical ideas presented in The Social Logic of Space (Hillier and Hanson, 1984) and b) as a coherent body of literature (Peponis and Wineman, 2002). In this section space syntax is reviewed as a body of literature in connection with the analysis of the relationship between spatial attributes and interaction behaviour.

12 The term actor indicates that the way they relate to time can occur at multiple levels of analysis from individuals to groups to organisations to societies (Ancona et al., 2001).

13 A Pod is a group of four to six workstations surrounded by high panels around the perimeter of the group. A Bullpen is a group of four to twelve desks in an open space, without partitions or dividers (Becker and Sims, 2001).

14 Their paper does not delve into Markov's theory, they only say that " the "Markov property" defines the next state as depending solely on the current state" (Su and Mark, 2008: 87), and refer the reader towards Nelson, B.L. Stochastic Modelling: Analysis & Simulation, McGraw-Hill, New York, NY, USA, 1995.

15 These probabilities are "derived from frequency counts of the observed data" (Su and Mark, 2008: 87).

16 Volume of participants and location are included in the 5th column because they are reported observable outcomes of interaction activities. It is not clear in the literature if it is the combination of temporal variables and conditions that influence the volume of people and location of events or viceversa. What it is clear is that this relationship is heavily influenced by the organisational context.

17 Cognitive burden, in educational psychology more commonly known as cognitive load, is generally considered "a multidimensional construct that represents the load that performing a particular task imposes on the cognitive system of a learner"(Paas and Van Merrienboer, 1994: 353). Two important mental-load characteristics of complex cognitive tasks are: "the number and nature of component skills involved (i.e., subskills that form part of the to-belearned skill) and the complexity of the goal hierarchies of the problems that must be solved in the task domain (i.e., the progression of goals that must be accomplished to reach a solution"(Ibid.: 355).

Chapter Four: Methodology

Abstract

The focus of this section is to describe a method that enables new ways to detect and record the flow of face-to-face interaction and solitary events inside buildings. An accurate and precise location tracking dataset is applied to this purpose. A new automated observational method is articulated based upon the concepts of personal space and interaction distance introduced in the previous chapter. A coding scheme is developed and used to define the mathematical boundaries of interaction and solitary events. These measurements are then used in MATLAB[i] to manipulate the raw location tracking dataset and obtain highly accurate location and time information of those events. The spatial and temporal measurements and attributes of interaction dynamics described in Chapter 3 are used to test the validity of the new method through a set of hypotheses. The case study also employs manual methods - observations, a survey, and two sets of interviews with a twofold purpose: a) to contextualize the technology deployment and the location dataset gathered and b) to portray interaction dynamics with current methods and provide a comparison of results. The chapter begins with a section introducing the research field of pervasive computing, focusing on indoor location technologies. Ubisense, the commercial location tracking system used in the case study, is described, and an argument for the use of this type of technology to understand behavior in buildings is presented. The main output of the thesis is a new method to use accurate location tracking data to understand some spatial and temporal aspects of the pervasive nature of interaction and non interaction dynamics, providing evidence on both its potential and its limitations.

4.1 Introduction

The work of the previous chapters reveal the effort that has been made to bring together perspectives that will allow for the creation of a method that can potentially offer unprecedented understanding of the nature of physical interaction in organisations. This chapter feeds from them and introduces a novel form of inquiry into the structure and organisation of face-to-face interaction and solitary behaviour. In this thesis, face-to-face interaction is treated as a domain in its own right (Goffman, 1983), characterised by a number of testable spatial and temporal conditions. Solo behaviour is understood as privacy regulation and as part of the process of openness and closedness that characterises interaction dynamics (Altman, 1975, 1976; Altman et al. 1981), which is also defined by spatial temporal features and attributes.

The previous chapter review of methods that different authors have developed and used to study face-to-face interaction shows a total dependence in human perception of behaviour. The use of observations to study face-to-face interaction based on categories and self-assessments of behaviour "involves a reliance upon natural human judgement of motive, intent, or result" that results in that "the machinery of interaction […] is taken for granted by the investigator using the category approach" (Kendon et al. 1975:4). The investigator is "forever limited" in what he/she can study of the phenomena of interaction (Ibid.: 4). Video and audio recording of activities, considered to be key instruments in the study of social processes "because these are the only means available by which behaviour may be "fixed" and so made into a specimen that can be repeatedly examined" (Ibid: 7), are also subject to interpretation on the part of the researcher, and while social scientists have used it to explore in depth verbal and non verbal behaviour (conversations, the mechanics of take-it-in-turns, body language, gaze etc), behaviour is continuous and seems to have a multilayered structure which is extremely difficult to agree upon and study.

The development of pervasive technologies, specifically indoor location technologies, in the last 20 years opens a highly sophisticated door to study behaviour as it happens, fix it in coordinates and analyse it in detail. The method proposed in this chapter differs from previous attempts to understand face-to-face interaction dynamics in the approach adopted. First, seeing those dynamics as a field in its own right characterised by spatial and temporal conditions that can be treated as data on its own terms (Goffman, 1983). The specific attributes of the building contributing to the encouragement and/or inhibition of interaction/non-interaction behaviour (Heerwagen et al., 2004; Rashid et al., 2006), as well as the temporal features that characterise them, have been identified and conform the hypotheses that help testing the new method. Second, using an accurate location tracking dataset as a tool to study behavioural events for, literature suggest, the aspects of interest for this thesis, are best studied at micro level units of time (McGrath and Kelly, 1986; Ancona et al., 2001),

This method is designed in the context of the knowledge organisation, companies that assume that knowledge is the most valuable resource of the firm and that new knowledge is created through the recombination and exchange of existing knowledge embedded in the minds of individuals (Nonaka, 1994; Nonaka and Takeuchi, 1995). The measurement of face-to-face interaction dynamics is imagined in those organisations, inside their physical structures (buildings), and the main aim of this innovative method is not only to introduce a new way of looking into the phenomena and advance academic knowledge in this area, but also to provide a useful decision making tool for managers, facilities managers and architects and designers of office buildings. Understanding the specific dynamics that are developed in different organisational contexts through time, is the first step to intervention in the company's productivity cycle and in the process of knowledge transfer and innovation.

The chapter starts with a description of the area of research called pervasive computing, focusing on indoor location tracking technologies and on the specific system used in the case study, Ubisense. This first section argues for the use of these technologies to measure face-to-face interpersonal dynamics and to cover the gaps left by current methods. The following section describes research design issues. Next, a description of the research methods, automated and manual, as well as the analysis and visualisation tools used in the thesis, is presented. Then, issues related to the case study access and pilot study site are outlined. The chapter closes with a general discussion on methodological considerations and limitations to the methodology proposed.

4.2 New means to measure the pervasive nature of human interaction processes

This section gives an overview of the pervasive computing research area, focusing on the field of indoor location and on the system that this thesis uses to obtain the location tracking dataset. Once the technical aspects are outlined the argument progresses, arguing why this type of technology can advance the study of interaction dynamics in organisations, what the specific characteristics that allow the researcher to observe systematically live behaviour in its naturalistic context are and what the advantages are over current methods that make the use of highly accurate location technologies an unique asset.

4.2.1 Pervasive computing research

Pervasive computing – often synonymously called ubiquitous computing - has been in development for more than 15 years, but "still remains some way from becoming a fully operational reality" (POSTNote, 2006: 1). Pervasive computing is the third wave of computing technologies to emerge since computers first appeared. The first wave, also known as the mainframe computing era was characterised by one computer shared by many people, via workstations. The second wave was the personal computing era, where one computer was used by one person, requiring a conscious interaction. In this era users are largely bound to their desktop. Most societies are moving out of this period and entering the third wave known as the pervasive computing era where the ratio is of one person to many computers. Millions of computers are embedded in the environment, allowing technology to recede into the background (Weiser, 1999).

A pervasive computing environment would be one "saturated with computing and communication capability, yet so gracefully integrated with users that it becomes a technology that disappears" (Satyanarayanan, 2001: 11). Some core technologies have already emerged, although the development of battery technologies and user interfaces pose particular challenges (POSTNote, 2006). It may be another five to ten years before complete pervasive computing systems become widely available.

4.2.1.1 Pervasive computing technologies: devices, connectivity and user interfaces

Pervasive computing involves three converging areas of ICT (Information and Communication Technologies): computing ("devices"), communications ("connectivity") and "user interfaces" (POSTNote, 2006).

Pervasive computing systems devices are likely to assume many different forms and sizes, from handheld units (similar to mobile phones) to near-invisible devices set into 'everyday' objects (like furniture and clothing). These will all be able to communicate with each other and act 'intelligently'. Such devices can be separated into three categories: sensors, processors and actuators. Sensors are "input devices that detect environmental changes, user behaviours, human commands etc"; processors are "electronic systems that interpret and analyse input-data"; actuators are "output devices that respond to processed information by altering the environment via electronic or mechanical means" (Ibid.: 1). Trends for the future development of pervasive computing systems devices involve the production of networks of devices that could be as small as a grain of sand, each functioning independently and with its own power supply and the ability to communicate wirelessly with the others. This cloud could be distributed throughout the environment to form dense, but almost invisible, pervasive computing networks (Kahn et al., 1999; Warneke et al., 2001). At the other side of the research vision spectrum, augmented reality would involve overlaying the real world with digital information, using mobile technologies, geographical positioning systems and internet-linked databases to distribute information via personal digital companions (Lee et al., 2008).

A wide spectrum of devices may become available in the near future. Some of them exist today – mobile phones and PDAs (Personal Digital Assistants), but the future seems to span a range "from miniaturised (potentially embedded in surrounding objects) to a variety of mobile (including handheld and wearable) devices" (PostNOTE, 2006: 2). While these could exist independently from one another, it is likely that many will be interlinked into broader systems. Connectivity, data communication, the idea that "devices are everywhere and communicate with each other to provide users with the information they need when and where they need it" (Borriello, 2008) is one of the most commonly referred to aspects of ubiquitous and pervasive computing. Pervasive computing systems are foreseen to rely on the "interlinking of independent electronic devices into broader networks" (POSTNote, 2006: 2). This can be achieved via both wired (such as Broadband (ADSL) or Ethernet) and wireless networking technologies (such as WiFi or Bluetooth). Devices will be capable of choosing the most effective way of communicating with other devices and systems in different contexts. The effective development of pervasive computing systems depends on "their degree of interoperability, as well as on the convergence of standards for wired and wireless technologies" (Ibid.: 2).

User interfaces represent the point of contact between ICT and human users. These aim to be capable – going further than mouse and keyboard - of sensing and supplying more information about users, and the broader environment, to the computer for processing. Future input might be visual information –such as recognising a person's face - based on sound, scent or touch recognition, or other sensory information like temperature. Future output might also be in any of these formats. A key idea underlying most research in this area is that the technology could "know" the user, through expressed preferences, attitudes and behaviours, and tailor the physical environment to meet specific needs and demands. However, designing systems which can adapt to unforeseen situations presents considerable engineering challenges (Satyanarayanan, 2001).

The degree of control that users will have over user interfaces can potentially be either active with overt control over pervasive computing technologies and devices; passive, where technologies disappear and individuals would no longer know they were interacting with computers and the technology would sense and respond to human activity, behaviour and demands intuitively and intelligently; or coercive, where pervasive computing could control, overtly or covertly, lives and environments. There is an ongoing debate over which form will be dominant in future pervasive systems and each form has its supporters and its detractors. Greenfield suggests that “they be devised in such a way as to default to harmlessness, be conservative of time, be conservative of face, be self-disclosing and be deniable” (Greenfield, 2008:3823) in order to achieve an “ethical and responsible development of everyday ubiquity” (Ibid.: 3830).

To conclude, pervasive computing could have a range of applications, many of which may not yet have been identified. Applications in healthcare, home care, transport and environmental monitoring are among the most frequently cited. Research in these areas is taking place in industry and academia, often collaboratively, and some government activities are underway. But pervasive computing is an area of technology research that will still require the solving of technical and non technical problems for many years to come. Solving those problems will require a broadening of the technology discourse on some topics and the addressing of research challenges in areas outside computer systems (Satyanarayanan, 2001).

4.2.2 Indoor location tracking technologies

Location information is an important source of context for ubiquitous computing systems. The development of these technologies has been driven in the last decade by the need for understanding user’s contexts, knowledge that can in return help to integrate the systems seamlessly in everyday life (Hightower and Borriello, 2001; Roussos, 2002; Mannings, 2005). Position knowledge information of an object, person or animal is today a widespread requirement in many areas of business and social activity (Mannings, 2005). There are two main types of technologies and consequently systems that have been developed to respond to the challenge of localising and tracking entities either in outdoor or indoor environments.

Nowadays localisation outdoors is mainly provided by GPS (Global Positioning System). This is perhaps the most widely publicised location-sensing system, providing reliable and ubiquitous coverage allowing receivers to calculate their location to within 1 to 5 metres. GPS only works provided that the GPS receiver has “clear unobstructed line-of-sight view of at least four NAVSTAR[2] satellites” (Yang and Li, 2008: 560), which means that building walls and other objects in and around building environments obstruct those signals and in consequence degrade the performance of the system. This is the main reason for the development of indoor location technologies. In contrast with GPS, precise indoor tracking of people remains an open research problem, despite the range of systems developed and commercially available (Hightower and Borriello, 2001).

Indoor positioning is defined as “the technology through which the geospatial location coordinates of a number of mobile or stationary objects are determined in indoor environments. A typical indoor positioning system usually estimates the target object’s location from observation data collected by a set of sensing devices or sensors. When the target object is stationary the location estimation problem is also referred to as a localisation problem. On the other hand, estimating the location of mobile target objects is known as target tracking” (Yang and Li, 2008: 559). Indoor positioning is synonymous with “Geolocation; Localization; Location estimations; Bayesian estimation; Mobile robotics; Location tracking” (Ibid.: 559).

Positioning techniques developed for GPS and cellular networks do not work well in indoor areas, which has driven the development of different technologies including “enhanced GPS, location fingerprinting, superresolution time of arrival (TOA), ultra-wideband (UWB), radio-frequency identification (RFID), inertial navigation and dead reckoning, wireless local area network (WLAN) based localization, Kalman filters, particle filters, etc” (Yang and Li, 2008:560).

4.2.2.1 Properties of location systems

The properties of a location sensing system can be described and classified through a number of characteristics that allow its evaluation (Hightower and Borriello, 2001; Roussos, 2002a). Here, the key properties of interest are presented in the context of this thesis.

Physical position and symbolic location

This refers to two types of information, physical (Cartesian coordinates, x- axis, y-axis, geodesic coordinates, latitude, longitude and altitude), and symbolic or semantic (which reflects abstract ideas of where something is – in the bedroom, in the small office on the second floor, at the entrance by the pigeon holes, etc) (Roussos, 2002a). This is important because, “the resolution of physical positioning systems can have implications for the defitiveness of the symbolic information they can be used to derive” (Hightower and

Borriello, 2001: 58). This means that knowing to within 10 meters where a person or an object is inside a building may be effective to place the person or object in a floor, but is not effective if what is needed is to place them on a specific floor. If a system is purely symbolic it offers very coarse-grained physical positions[3].

Absolute versus relative

An absolute location system uses a shared reference grid for all located objects – i.e. GPS receivers use latitude, longitude and altitude for reporting location, a system based on UWB (Ultra Wide Band) technology uses Cartesian coordinates. In a relative system each object can have its own frame of reference – i.e. near the High Street. This distinction, together with the previous one, indicates what information is available and how the system uses it and it has also repercussions "for deducing derivative and higher-level spatial attributes, for example orientation (in which direction am I traveling?), velocity (how fast do I travel?) and connectedness (can I move from this to that location?)" (Roussos, 2002a: 8).

Accuracy and precision

A location system should report locations accurately and consistently from measurement to measurement. Accuracy is related to the "grain size" of the position information (Hightower and Borriello, 2001: 59), "the smaller distance that a system can differentiate" (Roussos, 2002a: 9); precision relates "to how often we can expect to get that accuracy", usually expressed as a percentage (Hightower and Borriello, 2001: 59). For example, a GPS can reach 1 to 3 metres accuracy 99 percent of the time. Accuracy can be traded for increased precision, but it will depend on the particular application. A location system in an office environment might only need to be accurate enough to determine who was in which room at what time and not who was sitting in which precise location at 12:05:00 p.m.

Shadowing and multipath are the two main problems for accurate and precise indoor positioning. Shadowing is a result of "reflection, absorption and scattering caused by obstacles – furniture, walls, between the transmitter and receiver and occurs over distances proportional to the size of the objects" (Kushki et al. 2008: 568). The main source of multipath is reflection caused by objects, and multipath propagation introduces shifts in the measured signal (Ledeczi et al., 2008).

Scale

This property refers to the capability of the system to locate objects either indoor or outdoors, at the level of a city or the level of a building or room, the number of objects that can be located within a certain amount of infrastructure and over a given time. The measurements for this would be "coverage area per unit of infrastructure and the number of objects the system can locate per unit of infrastructure per time interval" (Hightower and Borriello, 2001: 59; Roussos, 2002).

Cost

Hightower and Borriello list different ways of assessing the cost of a system (2001). Time costs – length of installation process, system administration needs; Space costs – amount of installed infrastructure, hardware's size and form; and Capital costs – price per mobile unit/infrastructure element and salaries of support personnel.

Limitations

This refers on one hand to the fact that some systems will not work in certain environments – i.e. outdoor versus indoor use is a common differentiation, and on the other hand, to the functional characteristics of different technologies. Both issues condition the kind of applications that can be built using different systems.

To conclude, location information for people has great potential for many innovative applications in indoor environments – i.e. shopping centers, museums, office buildings, hospitals and prisons (Yang and Li, 2008). Fine-grain indoor localisation is still a key missing piece for a range of applications such as "asset tracking in a warehouse or locating emergency personnel in a disaster area" (Ledeczi et al., 2008:1), or "tracking people with special needs, (and) help emergency workers as well as military personnel effectively complete their missions inside buildings" (Kanaan et al., 2008:91). Although there are numerous noteworthy results, there still exists significant theoretical and practical challenges especially for providing high-precision, cost effective, and scalable solutions indoors (Hightower and Borriello, 2001).

4.2.3 The Ubisense system

In the context of this thesis, focused on understanding interpersonal interaction and its dynamics, the choice of location technology is key to the final results. The main reasons for choosing an Ultra-wideband (UWB) system are that these systems are resistant to multipath propagation and have very good time domain resolution for localisation and tracking. UWB range measurements have demonstrated good accuracy and precision (Ledeczi et al., 2008). A fine-grained localisation system with a reported accuracy of about 15-20 cm was developed by Ubisense (Adlesse et al., 2001; Steggles and Gschwind, 2005). The Ubisense system is used in this thesis and this section describes its technical characteristics.

Ubisense is a platform for precise real-time location indoors. In their website, the company describe their product as follows: "A break-through in the application of a radio frequency (RF) technology called ultra-wideband (UWB) has enabled Ubisense to build a revolutionary real-time location system (RTLS) which delivers very high positional accuracy in traditionally challenging environments at reliability levels unachievable by legacy technologies such as conventional RFID or WiFi"(Ubisense home page, retrieved April 2, 2009 from www.ubisense.net); Ubisense claims 15cm 3D positional accuracy in real-time which – they say - enables rapid return on investment for the data generated and provides a level of transparency in complex processes which cannot be achieved intuitively or visually. All data captured by the system is recorded into standard relational databases such as Oracle or SQL Server.

4.2.3.1 Components: Ubisensors and Ubitags

The Ubisense location system consists of a network of Ubisensors, that are fixed in known positions throughout the area to be covered and networked using standard Ethernet[4] and a set of Ubitags, that are carried by people and attached to objects. Each Ubisensor has a conventional RF transceiver, and a phased array of UWB receivers. Each Ubitag has a conventional RF transceiver, and a UWB transmitter. The Ubisensors are organised into cells, typically composed of four to seven sensors, so that each cell covers a given area. Each cell has one Ubisensor that functions as its master.

The conventional RF channel supports bidirectional data communications between each Ubitag and the wider network, and each Ubitag is equipped with a pair of buttons and a bleeper to support control and paging applications. When a Ubitag is active, it sends out a conventional RF message containing its identity, together with a UWB pulse sequence that is used by the Ubisensors to determine the Ubitag's location. The Ubisensors use a combination of Time-Difference Of Arrival (TDOA) and Angle Of Arrival (AOA) techniques to determine the location of a transmitting Ubitag.

An individual timeslot is just over 26ms duration, leading to a maximum update rate per cell of just under 39Hz, though each individual Ubitag has a maximum update rate of 10Hz. (Steggles and Gschwind, 2005).

4.2.3.2 Ubisense technology advantages and limitations

This technology has three characteristics (provided that the system performs as claimed) that make it unique for the purpose of studying dynamic interactive processes: its precision, its real time response and its scalability.

This system can potentially sense where people and things are as accurately as people can, delivering, in a typical open environment, a location accuracy of about 15cm which can be achieved across 95% of readings. This allows location aware applications to tell exactly which room you are in, which computer you are seated at, which phone is closest to you and even which devices you are holding.

Ubisensors can track each tag several times a second. The system also dynamically manages the update rates of individual tags so that fast-moving tags will be located more frequently than stationary or slow-moving ones, simultaneously increasing system performance and battery lifetime. The Ubisense Platform also monitors real-time spatial interactions involving people and objects. For analysis, Ubisense provides historic reporting and playback of a user defined time period.

Regarding scalability, Ubisense uses a cellular sensor and processing architecture and low-cost off-the-shelf servers and Ethernet networks. In their website they claim that it can scale from a single room monitoring one person to very large complex sites - 100,000m^2 upwards, and can track tens of thousands of Ubitags in real time. Another advantage purported is that its installation is easily expandable, allowing it to start by monitoring key areas of a building and incrementally add areas to the system over time to monitor the entire site.

The disadvantages or limitations of using Ubisense for this particular case study are related to space and people. Particular problems derive from the deployment of the system in a physical environment and the fact that a significant number of users carry the tag around a building. These and related issues are discussed in depth in section 4.4.1 and in Chapters 5 and 6.

4.2.4 Advancing the study of human spatial and temporal behaviour in organisations

One of the main conclusion of Chapter 2 was that "(t)he economic value of a knowledge-creating firm arises through interactions among knowledge workers, or between knowledge workers and the environment (such as customers, suppliers or research institutes)" (Nonaka and Toyama, 2007: 25). One of the most important knowledge assets for a firm is the specific pattern of dialogues and practices each firm develops. Especially important are routines that foster creativity and at the same time preserve efficiency. These are "formed and regenerated through a dynamic interaction process and are difficult to grasp" (Ibid. 26). The human processes involved in the knowledge sharing and creation processes, such as conversations, "are difficult to quantify" (Ichijo 2007: 85).

Chapter 3 proves that understanding how collections of people use space and interact with one another and with the built environment through time remains largely untested by empirical verification. Partially successful attempts have been made from different disciplines to understand informal face-to-face interaction and the dynamics of interpersonal encounters - in the workplace, through time - all attempts suffering either from discipline blindness, studying interaction as part of wider phenomena, from lack of methods that are able to reflect the spatial and cyclic nature of interaction, or a combination of the three.

This has consequences for organisations and its managers and those who are involved in the physical design and management of the buildings. From a managerial perspective current approaches fail to provide information that enables the organisation as a complex dynamic structure involving people, processes, technology and a physical environment to be used to maximum efficiency, particularly in terms of appropriate adjacencies of people and protocols affecting the use of the workplace and the regulation of behaviour affecting productivity. From the perspective of building design and management, current approaches to the study of interaction provide only high level and general indications of how occupiers use buildings, and what the specific features are that might influence interaction and privacy at work, and fail to provide richer spatial and temporal information that can further inform design decisions.

Location tracking technologies can provide very precise position and time information which are the basis for a highly granular knowledge of interaction patterns. What these systems do not provide are the tools to transform raw location data into meaningful and manageable interaction information.

4.2.3.1 Covering methodological gaps

Methodological gaps identified in Chapter 3 point towards deficiencies related to the measurement of objective manifestations of multiparty behavioural events, in naturalistic environments and in real time. Current methods cannot capture interpersonal distances in naturalistic settings unobtrusively and in real time (Aiello, 1987). They cannot be used either to study gatherings of more than two people in detail or for a sustained period of time (Ciolek and Kendon, 1980). Regarding the relationship between interaction dynamics and the physical environment, the main methodological limitation seems to be related on the one hand, to issues of access to buildings which results in a narrow empirical basis – small number of participants, limited duration (Sundstrom, 1987; McCoy, 2002), and on the other, to a lack of current methods to measure interaction processes in buildings through time and pinpoint them on a plan. All these issues relate to the deficiency of current tools to study comprehensively the spatial and temporal dimensions that characterise the unfolding of social processes (McGrath and Kelly, 1986). Video and audio recordings are very rich in terms of information obtained but painstakingly difficult to process, highly time consuming and therefore costly to use.

The literature review conducted reveals the gaps that current methods have, but it also reveals that observations of interaction behaviour seem to be the most appropriate tool to study them systematically (McGrath and Kelly, 1986; Bakeman and Gottman, 1986). Researchers have often settled for static measures of interactive behaviour, in part for a lack of framework (Ancona et al., 2001) and partially because of the lack of basic understanding of how to gather sequential information at the micro-level and analyse it in a way that makes use of its chronological nature (Bakeman and Gottman, 1986; Perry et al., 1995). This multilevel challenge is bridged using an UWB system.

4.2.3.2 Why UWB technology

The three main reasons to use UWB technology and Ubisense, summarised in the previous section, are that it can achieve high accuracy and precision – around 15 - 20 cm across 95% of readings, it provides real time location of objects and it can be deployed across big complex buildings covering up to 100.000 m^2 with the potential to track tens of thousands of objects in real time (Steggles and Gschwind, 2005). These characteristics make it highly suitable for studying interaction dynamics. The technology provides highly accurate and precise real time location and time data and has the potential to obtain these data from a significant number of people simultaneously, capturing specific location of the events observed and their temporal characteristics through time. It can store all these data for its subsequent analysis. It can be deployed in a building to cover the whole of its shell, arguably without being disruptive for day-to-day work life[5].

It seems an ideal solution to the study of the "pervasiveness of cyclic processes in human interaction" (McGrath and Kelly, 1986: 171) and is infinitely superior to any other current method. Its potential limitations will be presented later in the chapter, but what it is important to point out now is the fact that using such a novel dataset allows for the first time, through the spatial and temporal relationships between the potential millions of data points obtained, an analysis of the unfolding of interactive behaviour in the workplace. It is not so much the highly accurate and rich information obtained through the system, as the structures and propositions that can be built on it that is the focus of this research and the value that can be obtained for different groups from such analysis. The significance of this research is its development of a method that enables the manipulation of the (raw, unprocessed, massive) location dataset and enables the transformation of that data into knowledge relevant to the design of buildings and the management of peoples' spatial and temporal productivity in the workplace. Current commercial location tracking solutions, such as Ubisense, do not provide the tools that allow such specific analysis. Other researchers around the world have used pervasive technologies to understand behaviour, and it is important to present here some of that research to highlight the novelty of the method proposed, for it provides information that was not previously obtainable.

4.2.5 Similar research worldwide

In the past decade, there has been a significant amount of pervasive computing research focusing on the recognition and discovery of high level activity in daily life, both in outdoors (such as the Cityware project http://www.cityware.org.uk/, Fatah gen. Schieck et al., 2005) and indoors environments using different location technologies and sensors (i.e. Clarkson and Pentland, 1999; Minnen et al., 2005, 2006; Eagle and Pentland, 2006;. Oliver et al., 2002; Horvitz et al., 2002; Aipperspach et al., 2006; Huynh et al., 2008; van Kasteren et al., 2008). All these works show that location and time are powerful cues to understand and predict the structure of daily life. But their focus is on activity recognition and time use and not specifically on face-to-face interaction spatio-temporal dynamics.

The research with closest affinity to that developed in this thesis is conducted by the MIT Media Lab Human Dynamics group; specifically their studies on Sensible Organizations (see http://hd.media.mit.edu/sensible.html). This group has developed and manufactured 300 wearable electronic badges called sociometric badges (Olguin et al., 2009) and used them to automatically collect behavioural data in real organisations. The device capabilities include recognition of sitting, standing, walking and running activities, extracting speech features in real time, sending, receiving and transferring data, indoor user localisation up to 1.5 metres, Bluetooth communication and face-to-face interaction time using and IR (infrared) sensor. Detection of face-to-face interaction is based on an IR transceiver module that detects when two people wearing badges are facing each other (Choudhury, 2004).

This group uses social signals such as "body language, facial expression and tone of voice" (Pentland, 2005: 64) derived from vocal features, body motion and relative location to measure "amount of face-to-face interaction, conversational time, physical proximity to other people, and physical activity levels in order to capture individual and collective patterns of behaviour" (Olguin et al., 2009: 1). Their findings contribute to the study of the relationship between co-presence and electronic communication, communication and social role and satisfaction level (Olguin et al., 2009), face-to-face interaction and productivity, and the relationship between interaction, proximity and location (Waber et al., 2007) in the organisations studied.

The main difference between this groups' approach and the one presented in this thesis is fourfold. This piece of work:

- focuses on understanding specific face-to-face interaction dynamics;

- uses a very precise location tracking technique;

- addresses in detail spatial and temporal aspects of physical interaction dynamics providing a framework for their study;

- is based on a system deployed by a third party over which the researcher had no control whatsoever.

The work of the MIT group aims to capture the underlying psychological processes that occur in the course of work interactions, whereas this thesis focuses on physical interaction dynamics. Also, the location tracking techniques used by that group are much coarser than those used in this thesis (i.e. containment, proximity). In general, they focus on similar objective aspects of behaviour – face-to-face interaction - but use a different approach to gather and interpret data. Although the mediating role of the physical environment is considered and the potential of the information obtained to feed the design process recognised, the MIT research does not include it in their analysis or potential applications. Temporal aspects are included but lacking a framework of analysis that they intend to refine in the future in order to look into the temporal relationships of the features observed (Waber et al., 2007).

Another fundamental difference between this thesis and this MIT group research is that their investigation focuses on designing and manufacturing wearable sensing technology with the purpose of measuring social signals, face-to-face interaction, location and proximity. This thesis though, starts with an interest in face-to-face interaction from an organisational and built environment perspective and attempts to measure it, covering current methodological gaps resorting to available technology and data.

The sociometric badge can capture only dyadic face-to-face interactions, not multiparty events. Also, to determine that the event is happening, it needs to look at segments of activity that last at least one minute. Its measure of physical proximity using its Bluetooth capabilities can only detect devices in an area of a 10 meter radius. The devices are in close proximity but that does not mean that their owners are interacting.

In conclusion, two aspects set this thesis and previous research apart. Firstly, the granularity of the location data obtained, with precise position and time data. Secondly, the object of study, face-to-face interaction and solitary time in organisations; this thesis is focused on patterning observable behaviour, not on measuring emotions or motivations.

4.2.6 Privacy in pervasive environments

Privacy in relation with pervasive technology, or the right of a person to be free from intrusion into matters of a personal nature, relates to the personal information that a person would not wish others to know without authorisation, and to a person's right to be free from the attention of others. As technology has advanced, the way in which privacy is protected and violated has changed with it. In the case of pervasive technologies its increased ability to gather and share personal information can lead to new ways in which privacy can be breached (Ackerman, 2004). Location tracking systems, specifically, can also create new ways to gather private information. Generally the increased ability to gather and send information has had negative implications for retaining privacy. The concept of information privacy has become more significant as more systems controlling more information appear.

Information privacy is sometimes referred to as “data privacy” and some others as the combination of that with “privacy of personal communications” (Clarke, 2006). One of the most common narrow usages of privacy is to refer exclusively to 'privacy of personal data'. In this case, individuals claim that data about themselves should not be automatically available to other individuals and organisations, and that, even where data is possessed by another party, the individual must be able to exercise a substantial degree of control over that data and its use. Privacy of personal communications implies individuals claiming an interest in being able to communicate among themselves, using various media, without routine monitoring of their communications by other persons or organisations. This includes what is sometimes referred to as 'interception privacy'

Location tracking systems have certain implications for both types of privacy, as a result of their ability to gather sensitive data – i.e. on users’ everyday interactions, movements, preferences and attitudes, in their capability to retrieve and use information from large databases/archives of stored data, and in their potential to alter the environment via actuating devices. With personal information being collected, transmitted and stored in greater volume, the opportunities for data interception, theft and "ubiquitous surveillance" (official and unofficial) will be heightened (POSTNote, 2006). These activities, if not reciprocal (that is, that individuals do not "know who is collecting the data, how the data will be used, how to correct errors in the data, and whether to expect a return"), are unacceptable (Roussos et al., 2003: 95).

Organisations have started populating their buildings with embedded devices, most of them with the potential for obtaining location information. Although the owner of the building is usually the firm, individuals consider part of their workplaces private, such as the toilets, common rooms, café areas and perhaps even their own desk or enclosed office. Data on many aspects of work life could be recorded and stored, with the risk of breaches of privacy. The arrival of these systems to organisations may mean that, after a period of normalisation or workers acclimatisation to, for example, wearing a tag or to see the sensors deployed, data can be collected without a person's knowledge or consent. Some argue that this could violate existing data protection law (POSTNote, 2006). This law also requires that personal data should be collected for a specified purpose only. Some others argue that this situation threats notions of identity and self, that need to be incorporated in the design and deployment of ubiquitous computing systems in real environments (Roussos et al., 2003).

However the opportunities for data mining activities could be vastly increased with these systems. Data mining involves processing large quantities of data to spot patterns and trends. In terms of building occupiers, workers data, this can lead to more effective targeted policies, procedures, structures and designs. However, because data mining activities can detect unknown relationships in data, some argue that there is the potential to violate existing legislation. There is debate over how privacy can be protected while still realising the benefits of the technology, and whether new legislation will be required (POSTNote, 2006; Satyanarayanan, 2001). Specific privacy practices have been taken in this research to protect individuals' identities (Steggles, 2003).

4.3. Research design

4.3.1 Case Study Research design

The research question driving the thesis is the desire to determine whether location tracking systems and the data they produce can be used to further current understanding of physical interaction dynamics in organisations. To answer to this, it is necessary firstly to develop a new method to explore this novel dataset [6]and, secondly, to test and validate it, in order to prove that the quality of the method is fitting for the study of physical interaction dynamics.

The research strategy chosen is the case study (Yin, 2003), for it allows both gathering location data and testing the hypotheses in a real life context, where the technology has been deployed and the data obtained reflect the phenomenon to be studied in its naturalistic setting, the organization. The case study also provides access to many sources of evidence necessary to put in context and validate the new method using current manual and other methods. This type of research strategy, finally, allows for the use of a mixed method approach, that is, the use of qualitative and quantitative methods to gather evidence and therefore to tackle many variables of interest.

A single case study has been used in this thesis, its exploratory and descriptive nature highly suitable for the exploration of the research question. Other reasons have contributed to this decision. First, the deployment of a highly accurate location tracking system in an office environment is a rare event nowadays. Second, access to the deployment of this type of technology and the Ubisense system in particular, has proven extremely difficult. The unit of analysis chosen is the individual, being specific sources of information *events* (Yin, 2003).

The outcome of the thesis therefore will be a new technique, based on accurate location data, developed, validated and tested in a real environment, its results contrasted to those obtained by currently used methods, to understand the flow of interaction dynamics in organisations, providing evidence on both the potential and the limitations of this new, automated, method.

4.3.2 Hypotheses

The aim of the automated method is to enable an adequate format and size of the interaction information. This process will allow for the segmentation, detection, representation, and will make visible temporal and spatial aspects of face-to-face interaction and solitary events inside buildings. The tool development is driven by the concepts identified in Chapter 3 and measured by a newly developed coding scheme. See Figure 4.1. The testing and validating of the new method is driven by a set of hypotheses also identified in Chapter 3 and formulated here. See Figure 4.2.

The coding scheme is based on the concepts and measures of personal space, interaction distance and privacy regulation. Codes are measuring instruments that "specify which behaviour is to be selected from the passing stream and recorded for subsequent study" (Bakeman and Gottman, 1986: 5).

Box 1. Automated coding scheme

- **Interaction Radius** – Interaction distance is defined as a bubble of 2.5 feet (0.75 m) radius around the individual: an area that marks the extension of the close phase of the individual personal distance.
- **Solo** - Solo behaviour occurs when one person's 0.75 m bubble is not overlapped by another person's for at least 10 seconds.
- **Interaction** - Face-to-face interaction occurs when one person's personal space boundary is overlapped by another for at least 15 seconds.

Figure 4.1 Behavioural codes used to develop automated method.

The new codes developed use the advantage provided by the potential of the technology to record precise position every second. They define the mathematical boundaries of interaction and solo events and interrogate the dataset using MATLAB. The triggers are the overlapping – or not overlapping - of a circular boundary of 0.75 m radius that has been drawn around each tag[7]. So, interaction is registered when two or more of those circular boundaries overlap for more than 15 seconds, and solo events are recorded when that boundary is not trespassed by another one at all for at least 10 seconds. These threshold values are arbitrary. The literature review presented in chapter 3 reveals that informal face-to-face interactions last often a few seconds, and that plenty of observed encounters of this type last less than 38 seconds. Nevertheless, a threshold for the analysis needs to be set up, and 15 seconds seems to be enough to presuppose that interaction, albeit brief, happens. Regarding solitary time, no evidence has been found towards defining at what point in time a person is to be considered as being on his/her own. The threshold chosen, 10 seconds, is purely arbitrary. The outcome information on interaction and non interaction events comprises frequency, duration and volume of people involved in the event[8].

Box 2. Hypotheses

H1 Knowledge workers spend variable portions of their working days interacting face-to-face and in solitary activities.

H2 Knowledge workers spend an average of 3 minutes in informal face-to-face interactions, most of them lasting less than 38 seconds. Solo events duration varies between 4 minutes and an hour.

H3 Knowledge workers spend more time interacting face-to-face the higher the number of individuals involved.

H4 Knowledge workers spend more time interacting face-to-face depending on the location of the interaction.

H5 Knowledge workers spend more time in solitary events depending on the type of location.

Figure 4.2 Hypotheses testing automated method potential.

This information will be used to test the hypotheses and hence the potential of the new method. It is expected that results will lead to the refinement of current knowledge on some aspects of the spatial and temporal nature of knowledge work. Hypotheses testing are not limited to the use of the location tracking dataset. Current methods used to gather behavioral data in organisations, related to the use of space and activities performed are used as well. The same hypotheses are used, and the results will be compared with the outcome of the new method for further examination of its potential.

4.3.3 Propositions

Testing and validating the new automated method needs to be put into the context of a parallel exploration of the impact that the deployment of a potentially intrusive technology has on the workforce taking part in the case study. The practical potential for increasing understanding of interaction in the workplace through the analysis of location tracking data depends critically on the acceptance by staff of these location tracking technologies. Interviews are used to understand staff perceptions and attitudes towards the technology and its deployment, their understanding of it and how those perceptions and attitudes changed through time. The propositions leading this part of the case study are summarized in Figure 4.3. In order to eliminate experimental bias no attempt has been made to make assumptions about how these issues would evolve (positively or negatively) nor to predict the results or the answers to the propositions.

Box 3. Propositions

P1 The experience of the surveillance will manifest itself in negative attitudes toward the technology deployment.

P2 Participants in the deployment will tend to mystify the scope and capabilities of the technology.

P3 Wearing the tag will raise complaints that will diminish through time.

Figure 4.3 Propositions.

This approach facilitates a research process that unfolds and evolves rather than being pre structured (and therefore constrained), an important criterion given the relative lack of existing research in this area. The propositions are used to initiate the study, but are developed as the research proceeds. Once the data is collected, analysed, and compared with the initial propositions, they are revised as necessary (Spradley, 1979, 1980; Spradley and McCurdy, 1972). N-Vivo, a computer assisted qualitative data analysis tool is used to analyse them. The results are presented in detail in Chapter 6.

4.4. Research methods

This section clarifies what type of data is needed to test the hypotheses.

4.4.1 Automated method

This section is entitled "automated method" but it could also be called "mechanical observation", "automated observational measurement "or "automated systematic observation". It is a bow to the value that observational methods in general have for observing the dynamic aspects of interactive behaviour and a call to attention for the reconsideration of observational techniques in the face of the sophistication of currently available location technologies (Bakeman and Gottman, 1986).

4.4.1.1 Accuracy, precision and quality of the dataset

It is necessary to point out that there is no such thing as a noise-free location technology. Put simply, noise is the difference between reality and the measure signal. Knowing that the *raw location dataset* is noisy, the key questions are, a) how to deal with the noise and b) what does it mean for the output data? It is worth mentioning that all of the measures taken, and described below, help only to reduce potential mistakes but do not solve them completely. Nevertheless, some steps have been taken to assure as much as possible the quality of the dataset.

Reducing noise

The dataset obtained consists of the following information: date, tag name, time in format mm:ss:ms, Cartesian coordinates associated with each tag, distance travelled between readings and number of samples taken per reading (see figure 4.7). Reducing noise implies diminishing the possibility of *false positives* (incorrect positive result), *false negatives* (incorrect negative result), and *systematic errors* (the system consistently reporting a negative result, i.e. interaction or the lack of it, a continuous false negative).

In this thesis, the steps taken towards diminishing the possibility of false positives are, on one hand, the precise measures driving the mathematical manipulation of data (a threshold of 15 seconds to detect activity and an area around each tag/individual of 0.75 metres) and on the other, that the system provides up to four updates per reading per second (this was decided by Ubisense).

Regarding potential false negatives, a number of steps are taken to smooth (taking specific steps to remove noise) the raw dataset. Firstly, the application of a Kalman filter[9], done by Ubisense on the raw data gathered by the system; secondly, the author has deleted all of the XYZ coordinates that equal the value 0, which equal those with very low readings, some due to low batteries and others due to people not wearing them and leaving them on their desks, deleted as well all rows/entries with a Z (height value) of either minus 0.5 metres or above 2 metres, leaving a margin of

0.5 metres left on both ends, and finally deleted all negative X and Y data points (incorrect readings) .

Systematic errors are the most important and the most difficult to detect. One can only tell, in this particular context – an office environment – by systematically measuring the position and duration of the tags' presence in desks. This exercise was conducted in the office environment by a representative of Nationwide, a Ubisense representative and the researcher. Accordingly, the sensor network was recalibrated and the tag position on individuals' necks altered. The location tracking system studied was able to calculate the position of tags worn by employees within the deployment area to an accuracy of 15 cm, this precision being obtained for 48% of the time. Two, independent from each other, accuracy tests were conducted during the time the system was deployed in the office environment in order to determine this number. In the third week of the deployment, it was agreed by both technology provider and organisation, that it would be desirable to gather data of space utilisation by observation to determine the quality of the data being gathered automatically by the Ubisense system. The tests were as unobtrusive as possible and required minimal amount of effort from a data gathering point of view while ensuring that sufficient data was obtained so that there was no significant sampling error. The first test was an assessment of what sightings were captured in the existing environment under ideal (artificial) circumstances that would maximise the system readings:

- tag worn high near the collarbone ;

- office nearly empty of staff;

- 6ft test subject, sitting completely upright at a desk.

The subjects of these sightings were three people wearing a tag each that recorded information on time of the day and time spent at which location, to be later compared with data gathered by the system. Sightings were tested at approximately 80% of desks and office cubicles in the area of the deployment. Using this method, which focused on the desk area or the cubicle area, 80% of sightings matched the system gathered data.

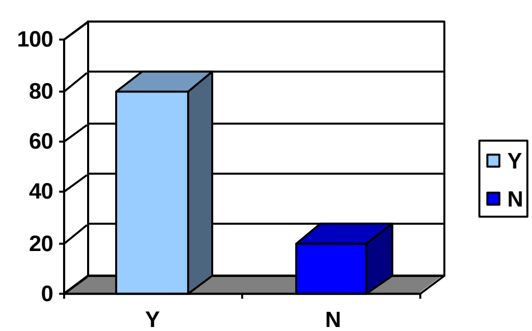


Figure 4.4 Sightings captured by the system under near ideal conditions. Ubisense data and chart.

The results of the systematic manual observations of space usage compared with the system sightings are shown above. A match between the manual and system is indicated by a 'Y' and no match between the observations is indicated by 'N'. So in the figure above, Y indicates good readings, N indicates nul or poor readings. Error bars are shown for a confidence interval level of 0.95.

The conclusion of this first test was that the system was not performing well for staff seated at desk positions, and that entry and exit from the desk zone were being missed as well. The best solution, proposed by the technology provider, was thought to be for staff to wear the tag as high as is comfortable, preferably just below the collarbone. Obviously staff couldn't be forced or coerced in any way to do anything about which they were in any way uncomfortable, and the technology provider was well aware of it. This piece of advice was communicated through an e-mail to all staff taking part of the pilot.

The performance of the system in the area of the desks and according to tag wear position introduces a significant variance to the quality of the promised results. The purpose of the second quality test was to be able to characterise system performance for desk zone occupancy and for tag wearing position. The technology provider proposed the following method to study these issues.

1 - A tag sub-type in the Ubisense configuration can be created that classifies the approximate tag wearing position. Staff should be quietly observed as to where they are wearing the tag. Each tag can then be classified to this sub type.

2 – A data extract into an excel spreadsheet according to the following fields. The granularity (observation time) should be 1 minute.

Example:

Zone	Time	Period(s)	Occupancy(s)
D12	11:00:00	60	35
D12	11:01:00	60	60
D12	11:02:00	60	60
D12	11:03:00	60	60
D12	11:04:00	60	35
D12	11:05:00	60	27

Table 4.1 Data extract of tags' occupancy.

3 – A similar table of Desk, Time, Tag position High, Medium, Low) is created for manual observation.

Desk	Time in	Time out	Tag Position
D-10	11:00:00	11:01:00	High
D-10	11:02:00	11:02:00	
D-10	11:12:00	11:14:00	
D-10	11:14:00	11:15:00	
D-10	11:16:00	11:17:00	
D-10	11:17:00	11:19:00	

Table 4.2 Manual observation template.

4 – Sampling error is minimised by observing a minimum 100 separate events per test run (where an event is a person/tag entering a zone, staying there for a period of time, and then leaving) over 3 separate runs, i.e. 3 x 100 events manually observed. Three people at 3 separate times should be sufficient to gather the data. Depending on activity level of staff, this will require an accumulated total of between 6 to 8 hours. More events sampled during this time will result in minimised sample errors.

5 - The tester (the IT person responsible for the deployment, the project champion and the thesis author) worn a tag, and sat at various empty desks. They moved every few minutes both recording their own time spent at a desk as well as observing a limited number of events around them. The whole of the deployment area was covered as presented in Figure 2.

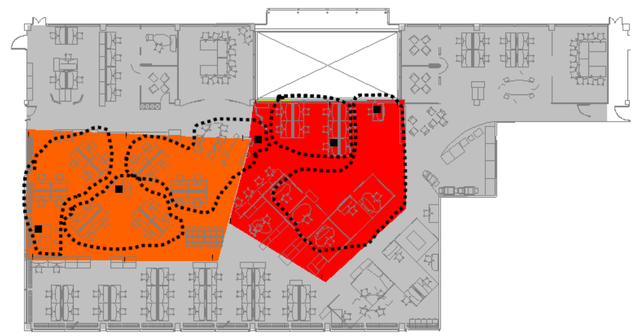


Figure 4.5 Desks observed and observation points.

6 – Observed data is compared to sensed data and determined whether there is a match or not. A Two Category Statistics test summarises this and present the quality per desk reporting zone with error values. This analysis was performed by Ubisense. The thesis author compared the manual data with the Ubisense results.

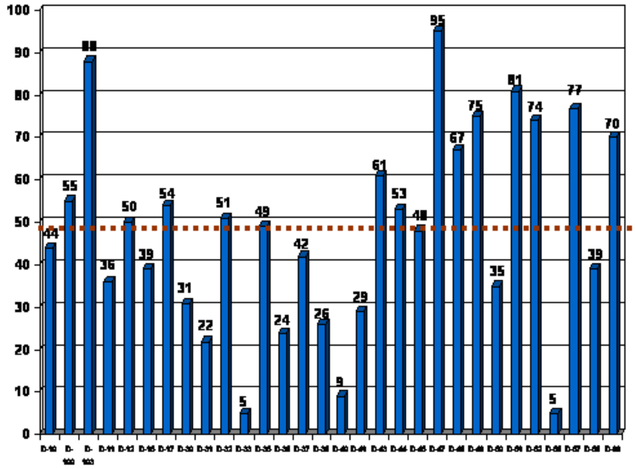


Figure 4.6 Average accuracy of the system per desk. Own analysis based on manual observations.

The dotted line marks the average accuracy of the system. The test was conducted with 30 desks. 51 tags were handed out. The columns represent the percentage of time that the system log and the manual observations coincide. The overall accuracy of the system is of 48% in recording space usage events at desks. These results although representing insufficient sampling, give an idea of the limitations regarding the accuracy of the data: 15 cm accuracy was obtained 48% of the time, in sharp contrast with company claims of 15 cm accuracy 95% of the time.

This relatively low precision is due to the combination of spatial and social reasons that affected the overall performance of the system. The spatial problems were, on the one hand, multipath errors caused by radio reflections in walls and objects and, on the other hand, shadowing (signal attenuation) caused by the overwhelming presence of metal in the environment. The situation was further complicated by the setting (a real environment), by workers' physical positions (hunched over their desks) and by their changing interest in the pilot (forgetting to wear the tags at times) which combined managed to influence the amount of readings obtained (see Chapter 6 on the experience and attitudes towards the technology for further details on these issues).

Consequences for the output data

These filtering and smoothing actions ensure, as much as possible, the suitability of the dataset obtained for the purpose of this thesis, namely the development of a methodology to study informal face-to-face interaction in buildings. This filtered raw location dataset – for it maintains the structure showed in figure 4.7 – needs to be mathematically manipulated in order to extract some meaningful information from the thousands of data which, without a direction and a purpose, are irrelevant to the study of interaction. The program chosen to do this is MATLAB. But before going into detail into the specifics of the application of the coding scheme, and in order to highlight its novelty, a brief look into other definitions of face-to-face interaction and the methods used to study it, is presented.

4.4.1.2 A new coding scheme

Other key Interaction measures

A review of research literature that focuses on the study of face-to-face interaction in the workplace shows that authors define interaction differently depending on the specific aspect of it they want to measure. Reder and Schawb measure events (observable actions) and discriminate between communicative and non-communicative events. Their measure consists of a count of observations of individuals engaged in face-to-face conversations, the number of people involved and its duration. They also record periods of solitary work (Reder and Schawb, 1990). Kraut and his collaborators define informal face-to-face interaction as brief and unplanned encounters. They identify face-to-face conversations occurring in a sample of locations. When the researcher identifies a conversation, participants in it were asked to complete a brief questionnaire describing it (Kraut et al., 1990). Whittaker and collaborators define a communication event as a "synchronous face-to-face verbal interaction, over and above a greeting" (Whittaker et al., 1994: 133). They exclude from this definition other types of mediated communication as well as "solitary actions at one's desk" (Ibid.: 133). Perry and colleagues talk about "in-person visits" or personal visits as an observation measure (Perry et al., 1995: 14). Becker and Sims, in their study of office productivity, observed interactions occurring in a number of workplaces, noted the interaction location on a floor plan, number of participants, length in seconds and its nature: work, non work, and both (Becker and Sims, 2001). Su and Mark observers recorded informal face-to-face interaction start and end time and number of persons interacted with (Su and Mark, 2008).

The manual methods used to test the hypotheses and help to validate the potential of the automated method share traits in common with all of these studies, since all of them involve systematic observation of a set of coded behaviours. This trait is also shared by the new automated method. What sets this new method apart is its capacity to accomplish this automatically using a new coding scheme that involves the use of precise location and time information.

			NAME	TIME	AVERAGE_X	AVERAGE_Y	AVERAGE_Z	DISTANCE	SAMPLES
Starttime	13-Jun-05 00:00:00		125	13-Jun-05 14:08:30	8.88	13.25	-7.63	17.08	1
Endtime	13-Jun-05 23:59:59		125	13-Jun-05 14:08:47	0.00	0.00	0.00	0.00	0
			125	13-Jun-05 17:58:25	0.00	0.00	0.00	0.00	0
			125	13-Jun-05 18:00:11	0.00	0.00	0.00	0.00	0
			126	13-Jun-05 13:32:20	11.64	15.44	0.71	4.07	1
			126	13-Jun-05 13:33:03	12.95	14.96	-1.01	1.54	1
			126	13-Jun-05 13:33:25	9.11	11.86	-0.76	10.08	1
			126	13-Jun-05 13:33:46	5.74	8.24	-1.36	3.08	1
			126	13-Jun-05 13:34:24	0.02	4.37	-2.83	13.99	1
			126	13-Jun-05 13:35:04	-7.65	-5.51	-6.31	14.68	1
			126	13-Jun-05 13:35:29	0.43	-0.60	-6.99	30.17	1

Figure 4.7 Example of raw location dataset: first 11 entries of an excel spreadsheet containing location data readings for 13.06.05.

Figure 4.8 Sensor network coverage areas and sensor position.

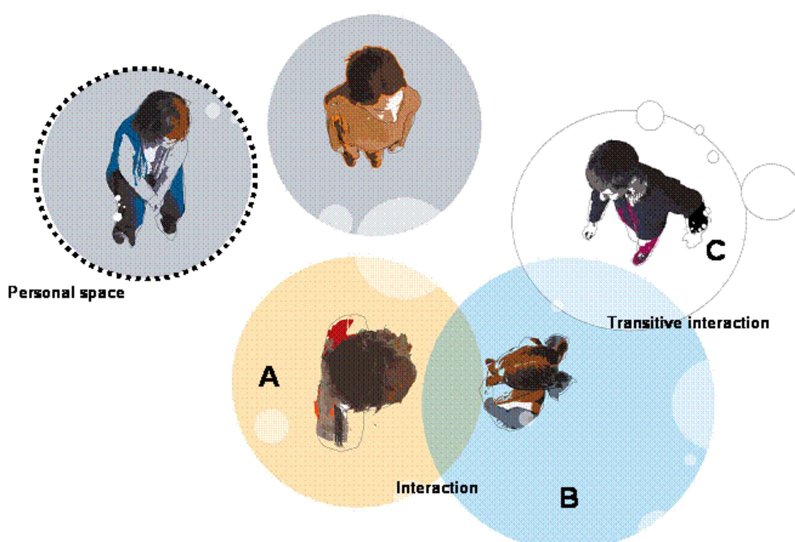


Figure 4.9 Personal space, interaction distance and definition of interaction[10].

New coding scheme

The development of the new coding system is lead by the question: what are the spatial and temporal behaviours that are pre-conditions of face-to-face interaction? The concepts of personal space, interaction distance and privacy regulation help shape the measurement of **interaction** and **non-interaction behaviour** as two sides of the same phenomenon. While Altman's research contributes in this thesis to the understanding of the role that privacy and personal space play in behavioural dynamics in the workplace, it is the concept of personal distance, based on the Proxemics research conducted by Edward T. Hall in the 1960's and 70's, that provides the distance threshold that allows for the developing of the new coding scheme.Codes measure behavioural states, and in this particular case the units used for recording are *events* of two kinds: solo and interaction. Each event has two states, ON and OFF. Onset and offset time of events and X, Y coordinates (location) for each event are identified and recorded. The behavioural codes used in this chapter are a means to extract specific spatial and temporal information of interaction behaviour in the context of the office.

MATLAB is the program of choice for the initial manipulation of the dataset. When a human observer is asked to identify events of interaction and events of solitary time, the unprocessed dataset has to be interrogated mathematically to identify and record those events. The triggers are the overlapping (or not overlapping) of a circular boundary of 0.75 m that has been drawn around each tag[11]. So, interaction is registered when two or more of those circular boundaries overlap for more than 15 seconds, and solo events are recorded when that boundary is not trespassed by another one at all for at least 10 seconds[12].

Interaction is also defined transitively: if person with tag A is interacting with the people with tag B and tag C, then A, B and C are said to form a cluster even if B and C are not within interaction distance of one another. See figure 4.9. Further manipulation proceeds according to the following algorithm for each positional record in turn:

1. If the tag in question was in a cluster and has moved away, then fragment that cluster into the parts that remain connected.

2. If the tag has come within interaction distance of another, then there are a number of sub-cases:

a. The two tags are both alone: form a cluster that includes both;

b. The two tags are already in the same cluster: do nothing;

c. One tag is in a cluster and the other is alone: form a new cluster that includes all nodes;

d. Both tags are already in clusters, and this movement joins the clusters together: form a single cluster from both previous clusters.

e. At the point a new cluster is formed, the time of formation is recorded, as is the centre of mass of the tags forming that cluster.

This manipulation of the raw dataset provides the output information used to describe a number of spatial and temporal aspects of face-to-face interaction dynamics set out in the hypotheses.

Location Factors

Hypotheses H4 (Knowledge workers spend more time interacting face-to-face depending on the location of the interaction) and H5 (Knowledge workers spend more time in solo events depending on type of location), are set to test spatial aspects of interaction and solo dynamics.

Precise location obtained after the manipulation in MATLAB acts as independent variable in the study of interaction behaviour. *Where* the different behavioural events happen adds a precise physical dimension to the temporal aspects also studied, powerfully enhancing the analysis and in consequence the results. The *where* has many layers of meaning and added to the obtaining of Cartesian coordinates per event the analysis will include the areas pre-defined by the organisation with some specific function associated, i.e. flexible areas, static desks, ancillary, and so on, as well as a visibility analysis of the layout to discover the visibility affordances of the particular environment.

Temporal factors

The temporal aspects of interaction dynamics identified in hypotheses 1, 2 and 3 should ideally be studied through the parameters occurrence, recurrence, duration, period or cycle, interval and rhythm[13] (McGrath & Kelly 1986; Ancona et al., 2001). To test the value of the location data this thesis limits the analysis to the simplest of measures: frequency and duration. The reason is twofold: the resources needed to accomplish this level of analysis are bigger than those available, and the lack of appropriate visualisation tools to represent simply and meaningfully the complexity of recurrence, cycles, intervals and rhythms. This is a challenge that needs to be addressed in the future and in a different context. In this thesis, occurrence and duration of events act on one hand, as independent variables to the study of interaction behaviour in the office environment, i.e. how does duration of informal face-to-face interaction affect its composition, and, on the other hand, as a methodology to study longitudinally the relationship of the behaviours under study, i.e. how does the relationship between duration and composition of interaction evolve through time (McGrath & Kelly 1986)? These time factors, combined with location factors allow for further refining of the hypotheses. See Table 4.3 for an overview of codes and hypotheses.

4.4.2. Manual methods

The purpose of using manual and other methods as well as the new automated method is twofold. On one hand, it serves to portray interaction and work related dynamics with current, widely used, methods and on the other hand, it provides a qualitative context to the deployment and use of a location tracking systems and advances knowledge on attitudes and perceptions of these technologies in the workplace. The data collection is designed to answer, as far as these methods permit, the hypotheses and is flexible enough to gather information from different sources, at different points in time, creating links between the methods and aiming to provide a picture of the specific socio-spatial and technological characteristics of interaction dynamics[14].

Coding scheme	**Interaction radius**	Personal space is defined as a bubble of 2.5 feet (0.75 cm) radius around the individual, an area that also marks the end of the private territory of the person
	Solo	Solo behaviour occurs when one person's private area is not trespassed by another person's for at least 10 seconds
	Interaction	Face-to-face interaction occurs when one person's personal space boundary is trespassed by another for at least 15 seconds
Hypotheses	**Temporal aspects**	Frequency Duration
	Spatial aspects	Precise location (X,Y) Type of area Visibility

Table 4.3 Automated method: summary of codes and hypotheses.

Observations of space use and activity combined with space syntax analysis of visual areas are used to develop an understanding of the office environment under study, specifically of the variety of different spaces available to support different activities, their visual affordances, and of the way these spaces are used by staff. The analysis of the data gathered provide the research with location and activity and visibility related information with which data from the location tracking system can be later compared.

Participant observation, photographs and interviews with staff are also employed to explore the more qualitative aspects of the use of the technology. These tools are used to understand staff attitudes to the technolo gy, their understanding of the technology itself, and how their attitudes towards it changed through time. A survey on work style and workplace behaviour is used to portray another aspect of the workers' work and interaction patterns. Workers on the floor wing where the deployment was set up were asked to self report on perceived ways of working and meeting locations and frequencies. Details on the data collection, analysis strategy and limitations are provided in the next chapter, where the case study site is described in full.

4.4.3. Analysis and visualisation tools

For the results of the automated methods, descriptive statistical analysis using Excel spreadsheets and visualisations of specific findings related to the hypotheses in Geographic Information System (GIS) MapInfo Professional are used. Results of observations of space are analysed through Excel and GIS software MapInfo Professional. The floor plan of the office environment is processed in Depthmap to form a visibility graph and measure some of the hidden attributes of the case study layout. The visibility graphs produced are overlaid on the findings to test hypotheses 4 and 5 on location of interaction – solo events. Participant observation and interviews are explored using computer assisted qualitative data analysis software N-Vivo. Questionnaire results are examined in the analytical software SPSS.

Of all the tools used, further detail is required regarding Depthmap, MapInfo Professional and N-Vivo, not because of their excellence as tools but because of their utility in this thesis for studying aspects of interaction.

4.4.3.1 Depthmap: Discovering visual affordances of workplaces

Visibility graph analysis is a spatial analysis technique for urban and building spaces. The method involves taking a selection of points across a space, and forming graph edges between those points, if they are mutually visible, to form a visibility graph. Having constructed the visibility graph it is possible to take measures of various features of the graph. So far, having been inspired by Hillier and Hanson's (1984) work, the pioneers of this research technique have concentrated on the integration of a point in the graph. The integration is a normalised (inverse) measure of the mean shortest path from the point to all other points in the system, which is the reason for the name of the technique: Visibility Graph Analysis Integration or 'VGA Integration' (Turner and Penn, 1999; Turner et al., 2001).

Various applications of this technique and new developments have been made by the space syntax community of researchers in recent years (Turner, 2007). The one of interest to this thesis relates to the link made by previous research between visibility integration, control and controllability and interaction and solo events (Doxa, 2001; Rashid et al., 2004; Allalouch and Aspinall, 2007).

4.4.3.2 GIS: Mapping human behaviour

A geographic information system or GIS, "…is a system designed to store, manipulate, analyze and output […] spatial information" (Steinberg and Steinberg, 2006: 7). GIS, or digital mapping, is key to both the display and improvement of positional information (Mannings, 2005). It has been argued that GIS is perfect for the study of social issues because it enables the user to visualise social and physical elements of a certain space over time, enhancing the analysis providing additional insights and information not previously considered (Steinberg and Steinberg, 2006). The use of GIS in this thesis is related to the unique opportunity to use highly accurate location tracking data to understand what happens where, to link interaction temporal dynamics with its location and to make use of precise location information that links interaction and non interaction events with their spatial location. It is not so much the information obtained through the location system as the richness of spatial analysis and the arguments that can be built on that information. GIS not only allows the visualisation or spatialisation of interaction events, it also provides a unique lens through which to examine the patterns and processes that concern this thesis (de Smith et al., 2007).

4.4.3.3 N-Vivo: Computer Assisted Qualitative Data Analysis

In this thesis CAQDAS, Computer Assisted Qualitative Data Analysis, is used to process and analyse participant observation and interview materials. In qualitative research, the analyst would normally go through a set of data marking sequences of text in terms of codes and for each code collect together all sequences of text coded in a particular way. A CAQDAS removes many if not most of the clerical tasks associated with manual coding and retrieving data. It does not analyse the information for the researcher, but it greatly facilitates the qualitative research process, thus the analyst must still interpret, code and then retrieve (CAQDAS Networking Project, 2008)[15].

The system chosen is N-Vivo. N-Vivo is designed for researchers who need to combine subtle coding with qualitative linking, shaping, searching and modelling.

N-Vivo is ideal for those working with complex data, such as multimedia, and rich text documents, and is especially useful for the researcher who wants to conduct deep levels of analysis (Jiron and Lee, 2005).

4.5 Research Design Quality

In this thesis there are different issues of validity and reliability related to, on one hand, the new automated method development and, on the other, to the manual methods employed (Trochim, 2006; Bakeman and Gottman, 1986). In order to address an adequate research quality of the new automated method, issues of construct validity and reliability of the system need to be dealt with. Construct validity refers to the degree to which inferences can legitimately be made from the operationalisations in the automated method development to the theoretical constructs on which those operationalisations were based. Reliability refers to the quality of measurement itself. In its everyday sense, reliability is the consistency or repeatability of the measurements. Both concepts are related, reliability is directly related to the validity of the measures proposed. Therefore, the measures proposed need to be reliable (consistent, repeatable) and valid (reflect the right thing) (Trochim, 2006).

In this thesis construct validity is an assessment of how well the new method has translated E.T.Hall and Sommer's concepts into a coding scheme and actual measurements. To do this, the thesis places the construct of interaction and non- interaction in the theorisation of personal distance and interaction distance concepts (Hall, 1959, 1966; Sommer, 1959); bases its operationalisation on Hall's informal distance classification (Hall, 1968); and provides data to support the construct.

On the other hand, validity aspects of the manual methods used in the thesis relate to the evaluation of the new automated method and the value of its results. Observations, interviews and questionnaires were used to compare results and determine its usefulness. Issues of the reliability of the new method are best contrasted with those pertaining to manual methods. Bakeman and Gottman state that "(t)he twin hallmarks of systematic observation are (a) the use of predefined catalogs of behavioural codes and (b) by observers of demonstrated reliability" (Bakeman and Gottman, 1986: 5). This affirmation applies to both sets of methods in significantly different ways. In the automated method section, a new method to study interaction using highly accurate location data is described. In the second section, manual methods, current observational strategies, as well as questionnaire and interviews and VGA analysis, are outlined. The main difference is on the effort made by the researcher. For the second section, regarding observational methods, the researcher has followed established and widely used behavioural codes used to study interaction and use of space in buildings, and so the effort made to develop codes and learn what to observe is minimal, for the researcher has had wide previous experience in doing this. For the section describing the new method, a huge effort in defining and develop coding schemes has been made. This can be seen by all the work reviewed in Chapter 3 and articulated in this chapter. Also, the methods differ in the source of the observations, which in this case takes the form of a technological system and as a measuring instrument, its reliability has to be established. So, while for the manual methods reliability is related to "training observers to acceptable levels of agreement" (Ibid.: 5), for the automated method reliability is established through its accuracy and precision, as discussed in 4.4.1.1.

4.6 Case study access and pilot study site

In order to explore the research question the main priority was to find a real environment in which the Ubisense system was already deployed or about to be deployed. In principle, the preparation for the case study followed three simple steps: to identify a knowledge-intensive company with such a deployment in one of its buildings or part of it; to contact and negotiate access to deployment, participants and data, including floor plans; and to conduct fieldwork ideally for a minimum of four to six weeks. Unfortunately events did not develop as planned and the search for such a company soon started to seem a highly impossible task.

Contact with the technology company, Ubisense Ltd. was open and friendly, but it was not part of their plans to involve an external researcher. The author was invited to participate in the pilot as a result of presenting her early research on workplace design at a seminar for facilities managers and following a series of meetings and communications with the Head of Research in the Property Development Department. Access to the firm's technology pilot was granted after considerable negotiation and signature of a non disclosure agreement (NDA) between UCL and Nationwide Building Society.

4.7 Limitations

No method or approach to the study of interaction in organisations will answer all the potential questions (Perakyla, 2004). In planning this investigation an approach was chosen with capabilities appropriate to the question of interest - can location technologies contribute to the understanding of face-to-face interaction dynamics in organisations? In interpreting the results obtained, there is an obligation to bear in mind the limitations of the approach presented (Wasserman & Inui 1983).

Three main types of limitations have been identified. Limitations regarding the multi method, single case study approach, the automated method developed and the manual methods employed. The specific inadequacies of the automated method related to the accuracy and precision of the dataset have been tackled in 4.1.1. Further social and deployment issues will be addressed in Chapters 5 and 7. Manual method limitations are discussed and addressed in Chapter 5, when the data collection process is described. Issues related to the multi method single case study approach are discussed here. A single unit design case study is a limitation that this thesis has converted into an advantage. Finding and obtaining access to a real knowledge office environment where a location tracking system used by a significant number of people was deployed, proved to be a very difficult task indeed. Once the case was found, the situation and the case were considered critical, and its use and results challenging to existing thinking and methods and so its use valid for contributing to research (Yin, 2003). Specific limitations relate to time and the nature of the data. The time spent on the case study, barely 8 weeks of combined methods and data, can hardly count as longitudinal[16]. But this time is enough to show the potential of the dataset obtained and the new method developed and illustrates its complementarity with manual methods. One of the key drivers of the approach was to deal with the quantitative richness of the dataset and its sheer volume. A six-week deployment with 51 people participating generates over sixty million location and time data points. Widely used data management tools such as Excel, Access, SPSS and others are not useful to deal with and present this volume of data in a meaningful format.

Finally, there is a risk in generalisation from the results obtained. The automated method cannot be used without fine tuning it first to the specific organisational context, and second to the capabilities of the chosen indoor location technology, but the principles formulated can be potentially used in any building and workplace after that adjustment.

4.8 Methodological considerations

It is important to point out that, on the measure of what is called privacy in this research; "there are systematic fluctuations in the desired levels for privacy and intimacy" (McGrath and Kelly 1986: 92). Individuals vary in the levels of need and/or desire to be with others and the need and/or desire to be alone, which in addition changes through time. A long-term description of the duality of this behaviour would be an "adequate descriptor of human social behaviour" (Ibid.: 92). This indicator can contribute to the measure of boundary-regulation mechanisms in the office environment. The method proposed attempts to identify these patterns by defining areas around individuals that, if overlapped for a specific amount of time, implies interaction; if not solitary time is implied. The results of the analysis through time in a real office, can throw light on the openness and closedness, and intimacy and privacy of the workforce as a collective and the stability and change of these behaviours (Ibid. 92). Changes in interaction/non interaction behaviour can signal a situation in which perhaps time is plentiful and individuals engage in more interactions and as a consequence, performance in the long term is possibly increased and innovation is created. These changes can signal also periods in which time is short and conceivably individuals may cut short interaction behaviour to focus on accomplishing individual targets (Ibid.: 100). If the causes are measurable – new contracts coming in or finishing, new recruits, redundancies, holidays, refurbishment or relocation – the effects can be identified down to the second and coordinated and potentially palliated. The potential to apply the measure of the practical aspects of interaction dynamics (where and for how long) can result in a more effective – as in qualitatively more efficient - workforce, through an improvement of the design of work and place structures (Perlow, 1995, 1999).

The coding scheme underlying the automated method development is based on theoretical and practical constructs that have been nonetheless put into context using previously gathered knowledge on the organisation, the layout and the group of participants in the pilot. The automated method has been fine tuned through the manual methods findings. In this particular case, the participants – 51 people – belonged to the same department and were divided into two units that worked side by side in a mainly open plan office. The deployment covered the open plan and four semi-open semi-private manager's offices. The observations of space use, movement and interaction behaviour carried out before the technology deployment offer a picture of a reasonably lively workforce, with plenty of 2 and 3 people conversations happening at desks and in flexible areas. This contextual information allows putting the theoretical assumptions to work for the tool development. A different environment would affect the assumptions made for this case study (Hall, 1966; Ciolek, 1983; Aiello, 1987)17. This study is focused in an office environment and with knowledge workers and aims to measure their collective unique interpersonal dynamics.

With the availability of technologies capable of sensing human presence and that can be used to measure behaviour systematically and – arguably, objectively, perhaps the researcher, manager and designer should seriously consider including location and time data logs into their own work, strategies and building design briefs. The decisive test of this newly gained knowledge will be in its application in real environments.

Key Points

- Highly accurate indoor location tracking systems fulfil the output data requirements needed to detect and record real time physical interaction behaviour in the workplace.
- The outcome of this thesis is a new technique to study physical interaction dynamics in organisations
- The automated method developed in this thesis makes a unique contribution to the study of observable behaviour in organisations.
- For the first time highly precise location and time behavioural hypotheses can be investigated in a real environment.
- Manual and other methods are used to contextualise and fine tune the technology deployment and to provide a background for methodological comparison.

Notes

[i] MATLAB is the program of choice for the initial manipulation of the dataset. This is a high-level language and interactive environment that enables the performance of computationally intensive tasks faster than with traditional programming languages such as C, C++, and Fortran http://www.mathworks.com/products/matlab.

2 NAVSTAR stands for Navigation Satellite Time and Ranging.

3 According to Keet, "(g)ranularity deals with articulating something (hierarchically) according to certain criteria, the granular perspective, where a lower level within a perspective contains knowledge (i.e. entities, concepts, relations, constraints) or data (measurements, laboratory experiments etc.) that is more detailed than the adjacent higher level. Conversely, a higher level 'abstracts away' – simplifies or makes indistinguishable – finer-grained details. A granular level is also called grain size and contains one or more entities and/or instances. Ideas about what granularity comprises can differ between research disciplines that tend to emphasize one aspect or the other. It combines efforts from philosophy, AI, machine learning, database theory and data mining, (applied) mathematics with fuzzy logic and rough sets, among others […]. Several interpretations of granularity capture subtle, but essential, differences in interpretation, representation, and/or emphasis" (2006:106). In the context of this thesis, coarse grain is used to refer to physical positions that do not provide very detailed location information, such as floor or room, and high grain or fine grain is used to refer to precise physical position in the format of Cartesian coordinates.

4 Ethernet is a local area network (LAN) technology that allows you to connect a variety of computers together with a low cost and extremely flexible network system (Spurgeon, 2000:xi). An Ethernet "is made up of hardware and software working together to deliver digital data between computers" (Ibid.: 23).

5 Participants in the deployment need to carry a Ubisense tag at all times to get readings.

6 Although the Ubisense system can provide very precise position and time information, it does not provide flexible tools to transform raw location points into a manageable data format that can be easily analysed to provide meaningful interaction dynamics information.

7 Whereas in the physical world this circular boundary is spherical, implying 3D or a 3 dimensional facet as described in chapter 3, in MATLAB a 2D or 2 dimensional circle is drawn around each tag in order to establish the threshold that trigger the measurement of behaviour.

8 Remember that this process transforms millions of location-time data points into thousands of relatively manageable, more focused data that needs to be further manipulated and compared with other sources to make practical use of it.

9 The Kalman filter, in simple terms, estimates the state of a dynamic system from a series of noisy measurements. A more technical definition describes the Kalman filter as a computational algorithm that processes measurements to deduce an optimum estimate of the past, present, or future state of a linear system by using a time sequence of measurements of the system behavior, plus a statistical model that characterizes the system and measurement errors, plus initial condition information (ATIS 2007).

10 Illustration created by the EU project IST – 2000 – 3104 HUMANTEC Design for Humanization of Technology http://www.ist-world.org/ProjectDetails.aspx?ProjectId=e9f944c19e1f45289225fdfd2e2edf2d

11 The distance chosen to define the interaction radius is a bubble of 2.5 feet (0.75 m) radius around the individual for this area marks the close end of the personal distance zone of the person. Hall estimated that an individual's intimate distance ends at 1.5 feet, where the personal space starts, which in turn ends at 4 feet; at its closest "two people barely have elbow room" but still they can "reach out and grasp an extremity" and they are still inside touching distance (Hall 1968: 92). "It can be stated with a great deal of confidence that people will become uncomfortable if they are approached at a distance that is judged to be too close (typically defined experimentally as 18 in./2.5 feet, or less)" (Aiello, 1987: 485). 18 inches has been used in the United States by researchers as the "boundary for an inappropriate approach" (Ibid.: 485), because Hall (1966) defined this distance as the outer edge of the intimate zone "into which adults generally do not allow strangers without sufficient reason" (Aiello, 1987: 485), – i.e. standing on a crowded tube, bus or concert hall). It is argued in this thesis that is the case with informal interaction in the workplace.

12 These threshold values are arbitrary. The literature review presented in chapter 3 reveals that informal face-to-face interactions last often a few seconds, and that plenty of observed encounters of this type last less than 38 seconds. Nevertheless, a threshold for the analysis needs to be set up, and 15 seconds seems to be enough to presuppose that interaction, albeit brief, happens. Regarding solitary time, no evidence has been found towards defining at what point in time a person is to be considered as being on his/her own. The threshold chosen, 10 seconds, is purely arbitrary.

13 "Occurrence of an event is when there is a change of state of that class of event, from OFF to ON. Recurrence of an event is when there is a sequence of state changes of that class of events, from OFF to ON to OFF to ON. Duration of en event, i, is the ONi – OFFi interval. Period of recurrence of an event – or cycle – is the ONi – OFFi- ONj interval, or simply the ONi – ONj interval. It cannot be negative, by definition. If it is zero, that is onset simultaneity. Interval between occurrences of an event is the OFFi – ONj interval. It can be positive (a gap), a negative (an overlap), or zero (continuity). Rhythm is an ONi – OFFi – ONj – OFFj – ONk – OFFk…sequence with either: (a) equal intervals between successive ON-OFF-ON sequences (equal successive periods); or (b) recurring identical sequences of intervals between successive ON-OFF-ON sequences" (McGrath and Kelly, 1986: 166).

14 Manual methods, specifically the interviews and the participant observation, serve a third (unplanned) function: that of quality control check for the performance of the deployment. Chapter 6 reports on findings related to these issues.

15 CAQDAS Networking Project, Retrieved from http://caqdas.soc.surrey.ac.uk/ April 8, 2009.

16 For an investigation to be considered longitudinal in scope, the data needs to span years or decades. In this case, the system collecting the raw location data would need to be in place for an extended period of time to affirm that the method/approach is longitudinal, a possibility that at the moment seems highly unlikely.

17 If the environment is a library, where the normal behaviour is characterised by individuals spending inordinate amounts of time inactive and at a close distance, a measure of the physical space would have to be done to understand the layout and the intimate distance would possibly have to be reduced to 0.5 feet – close intimate space. If the study was conducted in a high traffic museum, the assumptions would change accordingly with the audience behaviour.

Chapter Five:
Case Study Site

Abstract

This chapter offers specific detail about the Case Study site including the context, the organisation and the technology, how access to the site was negotiated and the strategy employed to gather and analyse specific strands of data. It introduces the dataset, the limitations faced and gives an overview on participation and ethical issues. This section presents the naturalistic environment whereby the research was conducted and it is the background against which the results of the thesis will be presented.

5.1 The Organisation

Between the end of May and mid July 2005, the case study base of this thesis was conducted at the headquarters of Nationwide, Swindon, UK. Nationwide is one of the biggest financial institutions in the UK. As with many others, Nationwide faces a changing and competitive market in which technology can provide an advantage. Technological awareness is therefore a priority for Nationwide and other such knowledge intensive organisations. Staff costs account for the majority of operating costs for businesses such as Nationwide with property costs typically constituting the third largest element of operating costs. Information on the performance of these resources and assets can play a role in improving organisational performance and productivity. Technology that can provide accurate real-time information on the location and movement of staff through space are of particular interest to large organisations such as Nationwide. Knowing, in real time, the location of their workers gives companies "the option of measuring, understanding, monitoring and managing their buildings better and the chance to investigate the relationships of the building to the day to day experience of each employee over time"[1].

In common with many large modern organisations Nationwide uses branding to communicate with the public and with staff. Nationwide overtly encourages staff to internalise the organisations' values and to accept its culture. Within the Swindon building, corporate branding exemplifies the corporate culture and values, and is highly visible around the building. Typical examples of this branding are posters and signs displaying the Nationwide motto and Nationwide's five-year PRIDE[2] campaign. At the time of the pilot Nationwide had been voted 'Best Big Company To Work For' in a national survey and this achievement was widely publicised. Surveys and interviews with staff, forming part of this thesis, reveal a complex relationship between staff and organisation but suggest that the high profile branding may have some impact on staff attitudes to Nationwide and their understanding of its ethics. This point will be discussed in depth in Chapter 7.

Technologies capable of providing organisations with information on location and movement to support increased performance can also provide unparalleled opportunities for employers to monitor staff and creates the potential for abuse. The issue as to how organisations can properly exploit the potential of these systems while the rights of individuals are protected against abuses is recognised by the author as critical to the ultimately successful deployment of these technologies. Some aspects of privacy have been discussed in the previous chapter; other aspects specific to the deployment will be discussed in sections 5.7 and 5.8. However, privacy protection in the workplace is not the primary focus of this study.

5.2 The Smart Space pilot study

In 2005 Nationwide set up an ambitious and novel technology pilot project. This project continued to be explored well into 2006. The Smart Building Project was an initiative promoted by the Property and Facilities Management team to assess the potential for new and emerging location and tracking technologies to improve Nationwide's use of space. The project had three operational phases[3]:

- Phase I was to install and test a passive RFID (Radio Frequency IDentification) security system to monitor numbers of staff moving in and out a defined pilot area.
- Phase II was to test and apply RFID tags to physical assets and link those to individuals' tags to cross reference their ownership and movement inside the building.
- Phase III was to install and test a location tracking system using Ultra-Wide Band (UWB) technology, Ubisense system, to monitor the precise position and movement of staff within the pilot area.

The author was invited to participate in Phase III of the pilot by the Head of Research in the Property Development Department. The Head of Research took the role of project champion for the pilot. The research presented here focused on results of the Ubisense tagging system carried out in Phase III. The location tracking dataset was used to explore physical interaction in the office and observations and interviews were used to study the spatial and psychosocial arrangements surrounding the introduction and deployment of an UWB system. During the Nationwide Smart Space pilot 51 staff were tracked, using Ubisense tags, for a period of 6 weeks. The author was given full access to the building, to the staff and to the location data produced by the pilot from mid May to mid July 2005.

5.3 The Office Environment

The pilot system was installed in Nationwide's headquarters building, Nationwide House, a modern purpose - built structure on the outskirts of Swindon. The building has lower ground, ground, first, and second floors. It is open 24 hours a day, 7 days a week. Its main design feature, as a building, is a street-like layout incorporating a third of the ground floor area. This is the building's main public space in which its shared facilities are concentrated. An Internet cafe, restaurant, convenience shop, and free coffee vending machines are located along the main street area.

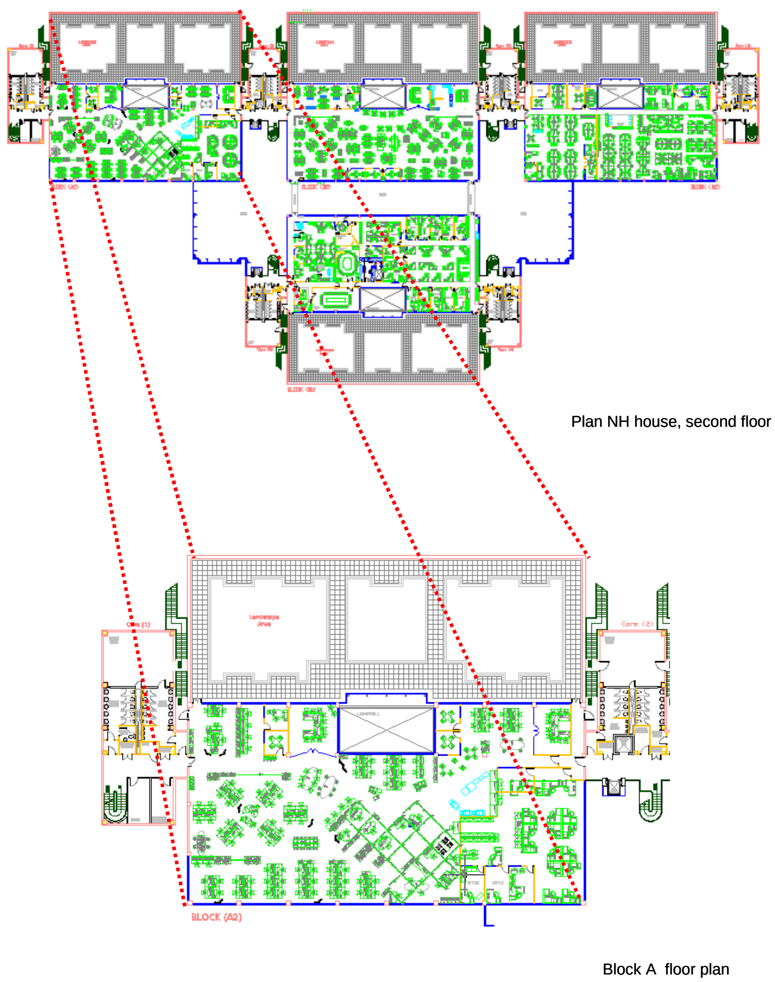


Figure 5.1 Nationwide house floor plan: Block A highlighted.

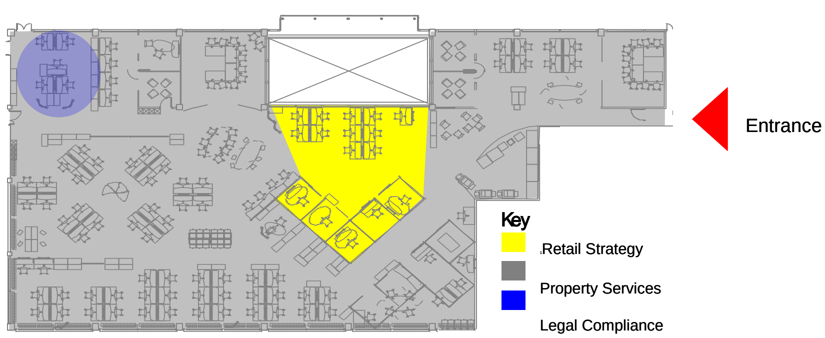


Figure 5.2 Office environment plan and departments involved in the case study (A2 room).

The pilot was conducted on one wing of the second floor; Block A2 (see Figure 5.1 and Figure 5.2). This space is shared by three different departments: Property Services (PS), Retail Strategy and Planning (RSP), and Legal Compliance (LC). This wing is occupied by 111 people in total. However, only the first two departments took part in the UWB technology pilot project with a total number of 51 people involved. When the area illustrated by figure 5.2 is mentioned, it will be called A2 room.

The three departments are accommodated in a single open plan area. The first impression is of a flowing open, although somewhat labyrinthine, space. This flowing feeling is underlined by the use of a sinuous red carpet detail that runs across the length of the floor plan. The labyrinthine aspect is formed by a metallic structure that houses the senior management staff in the middle-bottom part of the plan. The mixture of openness and enclosed spaces makes for an interesting mixture of private, semiprivate, semi-public, and public areas that have different types of use, ranging from static fixed positions to highly flexible drop-in areas, from quiet to break-out areas. The space includes two big meeting rooms often used by outside departments.

The Ubisense system was deployed some weeks after the installation of an RFID-based localisation system, Phase I of the Nationwide Smart Space pilot. Before the UWB system became operational, Nationwide staff were already carrying two tags: a Nationwide security pass and the RFID pilot project tag. When the Ubisense system was deployed, the 51 staff taking part in the pilot had to wear a third tag.

5.4 The Technology[4]

The UWB element of the Nationwide Smart Space pilot is, as far as the author knows, the first large scale deployment of a highly sophisticated location tracking system in a working office environment in the UK, and the second such deployment in the world[5]. Nationwide set up the pilot project to test a number of technological possibilities in order to be able to measure, understand, monitor, and manage their buildings, how they operate, and their relationship to the day-to-day experience of each employee over time. The Ubisense system was deployed for a total period of six weeks as a temporary technology pilot. Nationwide was interested in the potential for the system to be mobile and easily deployed in different floors and different buildings.

The system in operation and applications used was tested in a real office environment for the first time in this pilot, and some of those applications were specifically developed for Nationwide. Ultra-wide band technology was in its early years at the time, and its use until the year the pilot was conducted was restricted to a few secret military applications. The manufacturers of the system claimed it was the most accurate commercial indoor location - tracking solution available. The key interest from a research perspective in such a system is the granularity of the data that is gathered. The Ubisense system, unlike other RFID based systems, provides a point position for each tag by measuring the time taken for a signal from the tag to return to an array of sensors. At the time of the study, RFID by contrast merely confirms the presence or absence of a tag within the proximity of a sensor. In simple terms RFID systems rarely discriminated at that time more precisely than to confirm that a tag is in a room or at a desk. UWB systems offered then the potential to track the location of a tag to an accuracy of a few centimetres within a room or open plan area. This degree of accuracy allows the researcher to investigate patterns of human social behaviour that are not apparent from the coarser grained RFID data existing at the time of the study.

The system uses ultra wideband radio to determine locations of people and/or assets in indoor environments. Ubisense technology can also measure orientation, but this feature of the system was switched off and not used in the Ubisense pilot study.

Radio pulses are transmitted from tags worn by employees as they move about the office environment. The pulses are received by sensors mounted around the periphery of the building or rooms within the building and these calculate the position of the tags in real-time. The location data can be used in this raw form or it can be used to determine location events, i.e., when did a person enter the 1 m × 1 m zone in front of a desk, or how long was a person in a corridor zone? In the trial, all the data gathered was stored in a conventional SQL (Structured Query Language) database.

As it has been discussed in the previous chapter, the reliability of the locations and events recorded is critical. Determining location accurately in indoor environments is very difficult to accomplish. Among the main reasons for this are radio reflections in indoor environments causing errors (multi-path) and metal obstructions blocking the direct path of the radio signal (shadowing). The main reason for using UWB for indoor location tracking is to overcome the multi-path problem. Radio waves of different frequencies are reflected or absorbed differently by different materials. The idea behind UWB is to use as broad a spectrum of signals as possible to ensure that at least some are received by the sensors. Sophisticated signal processing techniques are then used to filter out 'noise' and determine an accurate position.

In addition to supplying the sensor and tagging hardware, Ubisense Ltd. also supplied a software application to measure space utilisation. This application takes the raw XYZ data and translates it into information on the frequency of use in predefined zones in the building (see Figure 5.3). The rationale for this is that such an application provides far more reliable and useful information than can be gathered by other means (e.g., manual surveys) in a form that is useful to the end-users of the system, that is Nationwide Property Development Department. Ubisense Ltd. assured Nationwide that it would be able to calculate the position of staff within the pilot area to an accuracy of 15 cm with a 90 percent degree of certainty.

The technology provider agreed the following objectives with Nationwide:

- Install hardware and software to cover the study area and simultaneously track up to 51 tags.
- Track and record the locations of employees.
- Provide services to install, monitor, and configure the system.
- Provide tailored output of the space utilisation of predefined zones in the form of Excel spreadsheets (essentially a set of analyses from the database).

In addition, a display screen was installed in the pilot area allowing staff to see the location and movement of the tags within the pilot area in real-time (Figure 5.5 and Figure 5.6).

The set up, configuration, and initial testing to get the system into an operational state was expected to take two to three working days. Nationwide perceived this as an important feature in order to have minimum disruption to normal working activities. In practice, this schedule proved highly optimistic. The actual set up time lasted for 6 weeks.

Moreover, the equipment installed proved more intrusive visually than anticipated. Figure 5.4 shows a sensor fixed to the ceiling. In addition, a buffer can be seen. These buffers were retrofitted to control problems with signal interference from other sensors - a problem that had not originally been anticipated.

The floor plan shown in figure 4.5 shows the setup area and the sensor positions. A total of six sensors in Area 1 were used and (ultimately) seven sensors in Area 2, three more than the original estimate of ten sensors to cover the entire area. The approximate timescales for the trial were to start the installation, setup, and configuration on June 6, 2005, lasting two to three days, followed by approximately four weeks of data gathering, ending approximately July 1, 2005. In reality, it ended on the 13th July.

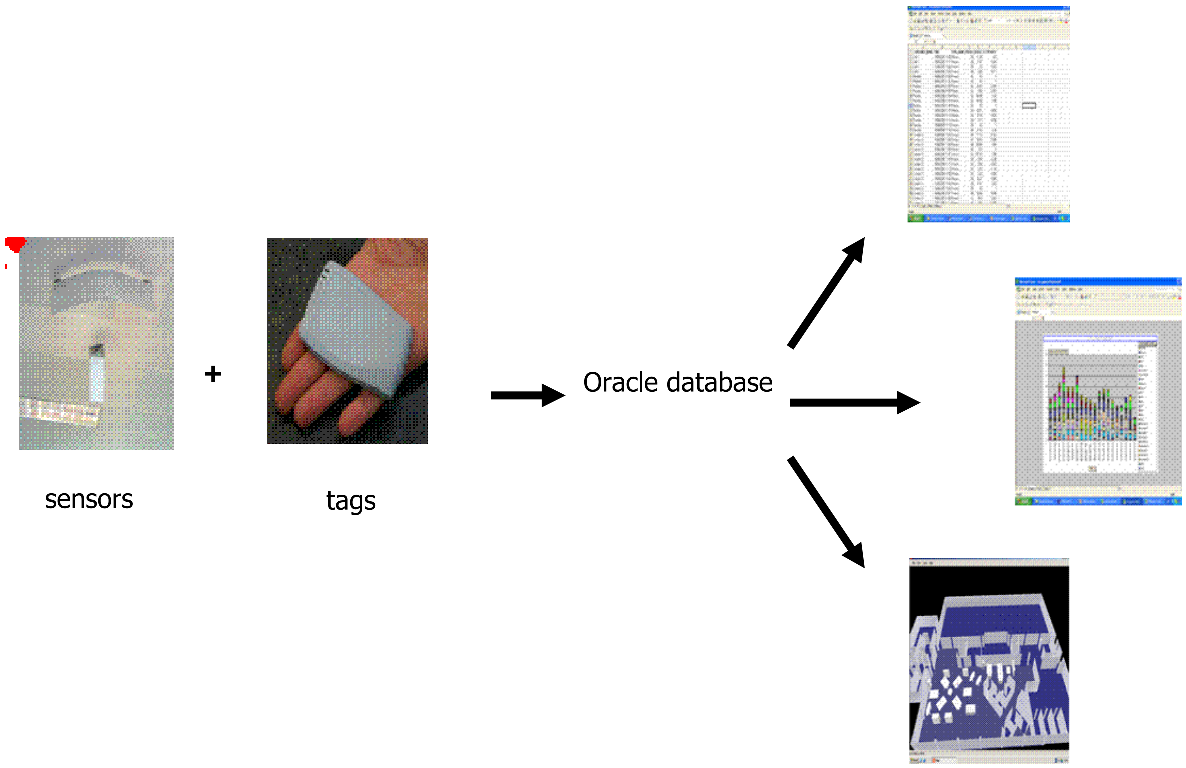


Figure 5.3 Ubisense system: Smart space application

Figure 5.4 Picture of the deployment: Sensor and buffer, June 2005, Nationwide House.

5.5 The Communication Strategy

The pilot was supported by an extensive, well-planned communication strategy aimed towards the staff in the A2 room. Communication between company and staff, was mainly by e-mail (see Appendix A for a full account of the messages and the different formats used), but three other communication channels were used: face-to-face conversations, a visual display, and visual cues, where the project champion and senior executives acted as exemplars of *when* (at all times) and *how* the tag should be correctly worn. As it will be discussed later (see Chapter 6), wearing the tag correctly had an important impact on the performance of the system.

This strategy was intended to explain each step of the technical deployment process of Phase 1 and Phase 3 of the pilot, what was expected from staff in terms of collaboration, the importance of the project to the company, and to diffuse concerns about data protection issues. Remember that these two phases involved different numbers of people. In Phase 1, all staff from the A2 room were involved. In Phase 3, only 51 individuals located inside the deployment area were invited to participate in the Ubisense pilot.

The project champion, the Head of Research and Development, gave a presentation to all staff involved in the pilot prior to its start. This presentation described the three phases of the overall project and the technologies involved, explained that the deployments were temporary and that participation in all phases was voluntary. One of the benefits of this presentation was to allow staff to put a face and a name to the project and, thereby, open up two-way communication through e-mail and face-to-face discussions through the course of the project. The Project Champion personally handed out the two sets of tags, explaining what they were for, how they should be worn, etc., and answering the questions people posed, mainly concerning radiation fears[6].

Through the presentation and e-mails, staff were informed of the physical extent of the pilot, its duration, the type of data being collected, and how the data was to be used. It also served to introduce the author as a UCL researcher and as another contact point to discuss the deployment and use of the technology. A web page on the company intranet was uploaded with the UCL researcher's picture and a brief professional profile.

The real-time display (Figure 5.5 and Figure 5.6) provided by the technology company aimed to give a visual check on the performance of the system. While not originally intended as part of the communication strategy, by placing the real-time display at the centre of the pilot area, staff had the opportunity to see and understand what data was being gathered through the pilot. This particular use of the display will be discussed in Chapter 6. Also discussed in that chapter is the impact the communication strategy had on staff understanding of the scope of the deployment and on their attitudes towards the technology will be considered.

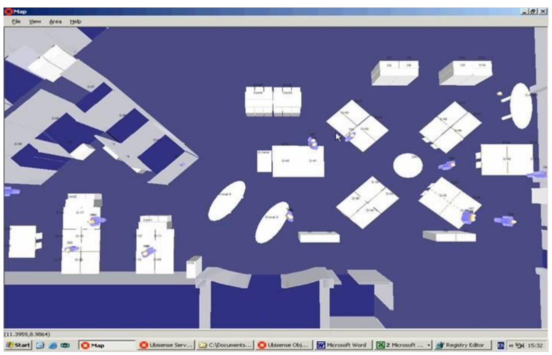


Figure 5.5 Real time time display, 3D representation of location and movement around the deployment area.

Figure 5.6 Picture of visual display in the office environment.

5.6 Data Collection and Tools, Limitations and Analysis Strategy

The data collection strategy involved gathering the location tracking data used in the new automated method, described in detail in the previous chapter, and a number of manual and other methods described in this section. The number of people involved in the whole research process makes this case study of greater scope and complexity than other such studies in temporal aspects of work (i.e.; Reder and Schawb, 1990; Kraut et al., 1990; Whittaker et al., 1994; Perry et al., 1995; Perlow, 1995, 1999; Becker and Sims, 2001, 2003; Su and Mark, 2008; Su et al., 2007), and spatial features of work environments (Backhouse and Drew, 1992; Rashid et al., 2004; Fayard and Weeks, 2007). The fact that the number of people wearing the tag is small (51 individuals) and the actual area of deployment quite small, may be criticised as too small a sample. But this small sample generates enough data to test the use of the technology-enabled method to study interaction, although the findings relating to it may not be generalisable. Furthermore, the reality that the case study involves just one organisation cannot lead to the claim that it is broadly representative of the phenomenon studied. Nevertheless, the research provides a multipoint perspective on interaction and non interaction dynamics. See table 5.7 for a summary of tools, number of people involved and timeline.

This section provides a description of the data collection and the tools used, the limitations[7] specific to the site and the analysis strategy followed.

5.6.1 System logs

Data Collection, Limitations and analysis

Nationwide asked the technology provider to install hardware and software to cover the study area, track and record the locations of 51 tags (employees), and to provide a tailored output of the space utilisation of predefined zones in the form of Excel spreadsheets. The data logs for this period cover all the events recorded by the system during the whole 6 - week period of deployment. There are gaps when the system broke down, and there are issues of reliability, limitation and analysis of the dataset that have been already mentioned and that will be discussed throughout the next chapters.

Even with gaps the massive volume of raw data obtained has been one of the main challenges of the thesis. The case study comprises 51 individuals wearing tags which update their location in the office environment every second. In a day, and provided that the system works and that all individuals wear the tag, i.e. no gaps, the system can potentially gather up to 1.468.800 location points. Widely spread software to manipulate, process and view data, such as Excel, can barely cope with the amount of data dealt with. Excel 2003 has a capacity of 65.000 rows on a worksheet and Excel 2007 has just over a million rows. The use of MATLAB and the coding scheme to lead the manipulation of the raw data allows producing information that first, is focused by the questions posed and, second, in terms of volume, is easier to manage.

There were also some specific analytical issues that had to be perfected and incorporated as the MATLAB manipulation developed. For example, it was discovered early on that if a tag leaves a cluster and then rejoins very soon afterwards, the sequence of events is recorded as two separate clusters, whereas in reality, it is likely to form part of the same interaction. Considering such hysteresis is complex, but it is likely to increase the time for which some clusters exist. Moreover, only the initial point at which a cluster was formed is calculated; so, for example, if two individuals walk through an office, their interaction point will be recorded as the point at which they meet. This was solved early on the code development and gives an example of the type of issues that have to be considered when creating a program that takes coordinates and translates them into data to be used to study specific behavioural activities.

5.6.2 Space use observations

Data Collection

Facilities managers working for efficiently run organisations in big complex buildings, regularly conduct space occupation and space use studies. They do this in order to understand numbers of people in different areas of the building, to be able to manage the use of space and, ultimately, to inform decisions on investment in property. In addition, these studies contribute to planning health and safety and disaster discovery procedures in complex buildings.

The methods commonly used today are reliant on human observers that count people and record observations in templates or on plans.

In studies of office environments observations are used to record space utilisation, the occupation and usage of space, counting the number of people in a particular space over time. Usage of space is recorded in terms of activity according to a pre-defined set of categories. See "British council for Offices Guide to Post-Occupancy Evaluation" for a comprehensive review of POE methods, examples of their use in case studies and a list of recognised POE methodologies (BCO, 2007)[8].

In this case, four activities were recorded: sitting, standing, talking and walking. The office space was also categorised in terms of space type, e.g. fixed desk, hot desk, break out area, meeting rooms, etc.

Tool	Type of data	Nature data	Number people	Timeline
Automated Method	Location coordinates, time updated every second	Quantitative Objective Continous Longitudinal	51	6 weeks
Observations space use	Observation activity coded	Quantitative Subjective Snapshot	111 plus visitors	4 days (2 before, 2 after)
Participant Observations	Diary logs	Qualitative Subjective Longitudinal	111 plus visitors	8 weeks
Interviews	Transcriptions	Qualitative Subjective In-depth snapshot	28 (16 plus 12)	4 days (2 before, 2 after)
Workstyle survey	Questionnaire answers	Quantitative Subjective Snapshot	71 out of 111	1 week
Depthmap	Selection of points across a space	Quantitative Objective Snapshot	All office	------

Table 5.1 Summary of tools, data gathered, participants volume and timeline of the case study[9].

The observations were recorded following a standard observation technique used by the Space Group - formerly the Space Syntax Laboratory – at UCL and complemented with qualitative observations of the office environment. The space use study was conducted over four days, two days before the UWB system was deployed at the end of May 2005, and two days after that, in the second week of the deployment at the beginning of June 2005. The observations of patterns of space use were made by using a standard technique in which an observer walked a circuit of all the spaces in the office environment at different times of the day and on different days of the week during working hours. The times covered were from 09:00 a.m. to 17:00 p.m. and the sample observed involved all staff present at the office on those days. The total number of staff at the time was 111 people[10].

On each round, the precise location and activity of every single worker occupying space was marked on a plan of the building. Each round took, on average, fifty minutes. Talking and static activity (sitting and standing) were noted in an anti-clockwise round by an observer making snapshot observations of the current activity in each space as she passed through it. Movement was traced also in an anti-clockwise circuit, in which the observer stood at pre designated points and noted the actual path walked by all people moving inside the zone visible from her vantage point during a five minute sampling period. The area covered by the observations, the zones' limits and the observation points are shown in Figure 5.8. Observations were then transferred to MapInfo Professional software to produce the graphics showing space use and activity patterns from Chapter 7. Activities were coded according to the following categories: Dot – sitting, Triangle – standing, Arrow – walking. In addition to this, groups of talking people were marked with circles. Each category and time slot was added to a different layer of the graphics file, so that different combinations could be graphically represented and statistically analysed. The results are shown in Chapter 7.

Limitations

Issues of accuracy also arise with manual observations. The accuracy of data gathered by human observers is necessarily contingent on the performance of the observers. Even with diligent and well trained observers the use of single observers recording the activities of a number of people in a space during a single instance necessarily introduces an element of judgement into the observations. However, similar methods are commonly used by researchers and consultants to gather data on space use to provide evidence based design recommendations. Also, in terms of flexibility and ease with which this method can be used, the use of human observers is, at this point in time, significantly less costly and more flexible than others involving different technology devices. Location tracking systems capable of providing granular data are currently complex to set up, relatively obtrusive and expensive. Technological developments are likely to see this change in the future.

Analysis

Observations of space use are used to develop an understanding of the office environment under study, specifically of the variety of different spaces available to support different activities and of the way that these spaces are utilised by staff. These observations provide the researcher with a context within which data from the location tracking system can be put into context, for the analysis of the observations is intended to describe patterns of space use and to capture information on interaction between staff. In commercial contexts, this knowledge is used to provide design recommendations aimed to improve the quality of the workplace, facilitate a process of change (i.e. towards flexible working), and to input the facilities management policies on health and safety, security, catering, etc. The analysis performed uses data gathered manually in templates and inputs it into MapInfo Professional, a GIS software programme to produce visualisations of activity in space through time in the office floorplan. Excel is used to manipulate the numbers and perform descriptive statistics of activity and movement through the period observed.

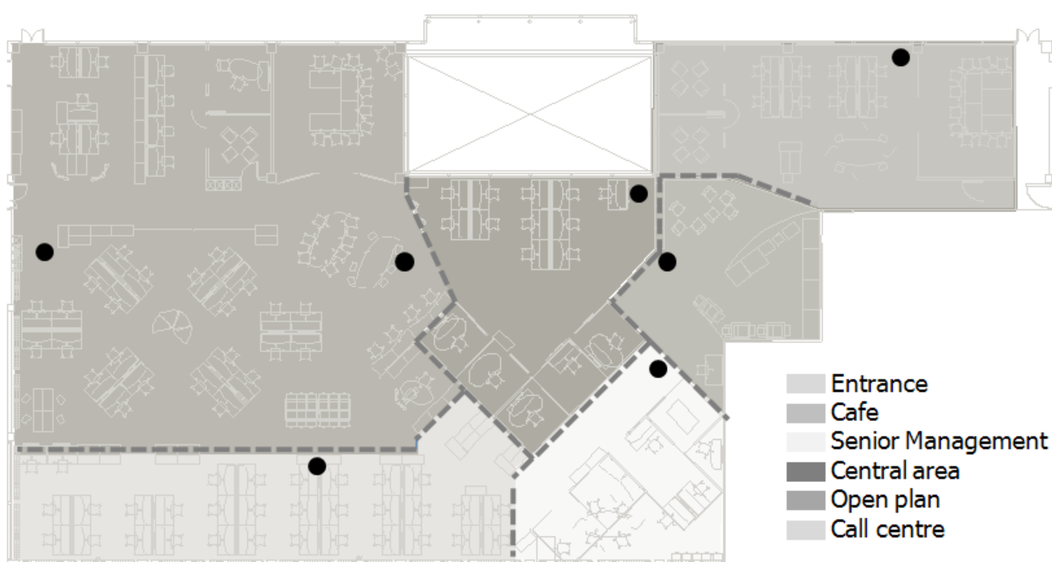


Figure 5.7 Areas observed and observation points.

5.6.3 Work style survey

Data Collection

The purpose of the questionnaire is to gather data on the workers perceptions on their workstyles and their meeting behaviour and to use this to contextualise the results of the automated measurement of behaviour. The survey template used was a standard questionnaire used by the Space Group at UCL. Specific questions on interaction (see annex D Workstyle survey; questions 10, 11 and 12) were negotiated with the project champion and incorporated in to the final version. The final questionnaire was addressed to all workers in the second floor room A2 at Nationwide Headquarters in Swindon. The target group was 111 people. The questionnaire consisted of 12 questions dealing with workforce demographics, work style and workplace interaction. The results are shown in Chapter 7.

Limitations

The main limitation of using similar questionnaires in offices is the usually low response obtained, that does not allow generalising across a population and forces the researcher to talk about trends in the data. This was not an issue in this particular case study for the response rate was unusually high. 71 questionnaires, out of a target group of 111, were filled in and sent back to the researcher, which amounts to a 64% response rate.

Analysis

Fourteen variables were defined, covering issues in three areas:

- **Workforce demographics:**

Variable 1 – ID

Variable 2 – AGE

Variable 3 – GENDER

These questions provide background information related to identification (a number for record purposes), age group and male/female distribution. It draws a picture of the population taking part of the pilot.

- **Workstyle**:

Variable 4 – CULTURAL BELONGING

Variable 5 – UNIT

Variable 6 – TIMETABLE

Variable 7 – DESK

Variable 8 – TYPE OF WORKER

These questions provide us with data on cultural belonging (amount of time spent within the company), the unit the respondents belong to, timetable, type of worker and the geographical distribution of the respondents in the office plan.

Questions on workstyle can be interpreted in conjunction with the results of the qualitative analysis, where issues of cultural and unit belonging are key to the attitudes towards the technology.

- **Workplace interaction:**

Variable 9 – VISIBILITY frequence

Variable 10 – USEFULNESS

Variable 11 – WORK WITH

Variable 12 – RELATION OTHER DEPT

The questions provide information on perceived visibility patterns, who sees who and how often, perceived usefulness of colleagues and formal work relationships. The list has 111 entries. Data on social networking, questions 9, 10 and 11, were discarded for the analysis and the results of question 12 used partially in conjunction with those of questions 13 and 14.

Variable 13 – HOLD MEETINGS

Variable 14 – ATTEND MEETINGS

These questions provide specific data on formal interaction related on one hand to the amount of visits workers pay to other departments, and, on the other hand, related to the physical areas where interaction happens and the frequency with which it happens. It draws a picture of formal and informal interaction in the office that hasn't been captured by any other of the tools employed so far.

The variables are nominal and ordinal, none of them is continuous; this has been a decision taken during the questionnaire creation, opting for Likert scales and grouping continuous variables such as age into a coded rank. This means that the results presented are limited to statistical summaries, frequencies and percentages and cross tabulations. See annex H for details.

5.6.4 Participant observation and Photographs

The purpose of gathering qualitative data in this case study – in the form of participant observation, photographs and interviews - is that it provides detailed understanding of the attitudes and behaviours of the pilot participants towards the technology deployment. Given these aims, an ethnographic approach was adopted. This approach attempts to see things from the perspective of others, to tell the story from the point of view of the user of the technology and not that of the researcher. Ethnography involves a type of observation in which the investigator is intimately involved in the social setting and the field research is a theory - generating activity (Spradley, 1979, 1980; Spradley and McCurdy, 1972).

The sources of data are the observed behaviours of the office workers across the eight weeks the researcher had access to the company, plus the opinions and accounts of the technology users. The techniques employed to gather information were ethnographic observations of the normal day-to-day behaviour of the office workers (participant observation), photographs, and in-depth ethnographic interviews of a cross section of those office workers wearing a Ubisense tag.

Data Collection

The participant observation was carried out in the office where the deployment was made. The researcher spent six weeks in situ, with a desk assigned, participating in the office routines and following a normal working day. The observation included not only the 51 participants, but the whole of the three departments located in the wing, as well as visitors, both internal and external. Diary notes were gathered between 19/05/05 and 13/07/05. Additionally, conversations and challenges raised by the deployment, exchanged via e-mail between the organisation, the technology company and the author, were registered and included in the analysis (see annex C and F for details).

Photographs of the office environment and of the technology deployment were taken. Despite being granted permission and the date of the photography publicised, workers were very reluctant to appear on them. See annex G for a visual description of the site. The results of the participant observation are discussed in Chapter 6.

Limitations

The main limitation of this technique refers to the choice of ethnography as a fieldwork approach. Critiques highlight its journalistic, unscientific, descriptive, non-analytical and subjective nature. Nevertheless, this is a style of research that is committed to studying people's understandings, meanings and practices in a naturalistic setting, and that allows the researcher to investigate and probe the high level research propositions described in Chapter 4. A limitation derived from practice was the restricted eight - week observation period available. It was not longitudinal enough to perform a sound ethnographic interpretation, but it was useful to draw a picture of some of the issues surrounding the deployment. Together with the interviews it formed a very powerful tool for understanding workers' attitudes towards the technology.

Analysis

The analysis of the participant observation was done in conjunction with the interviews. See the next point, analysis.

5.6.5 Interviews

Data Collection

Two sets of interviews were conducted, before and after the system was deployed. The first set of interviews was conducted with a subset of the 111 individuals in A2 room, already wearing RFID tags. The second batch of interviews involved a sample of the 51 individuals wearing the UWB tag. A total of 28 interviews were carried out. They ranged in length from 6 to 57 minutes. The difference in duration is due to the nature of the interviews, ethnographic. The interview template had a loose structure to try eliciting information from the participants. Some engaged more deeply in the explanation of the different questions and some other did not. The first set of 16 interviews was conducted over several days in June 2005, before the deployment of the UWB system. The second set of 12 interviews was conducted in mid-July 2005, during the last days the UWB deployment was in place.

The first batch aimed to find out about a) the general experience of carrying a tag that users knew was tracking their movements; b) their understanding of what the location technology scope was; c) their understanding of the next step, the Ubisense deployment; and d) the benefits perceived (if any). The approach involved asking semi-open questions that allowed the informants to develop a narrative and express their opinions. The second batch of interviews followed the same line of inquiry in order to evaluate the effect of introducing the UWB system. These were bigger and heavier than the RFID tags, and were worn hanging from the neck instead of in a pocket or on the shirt.

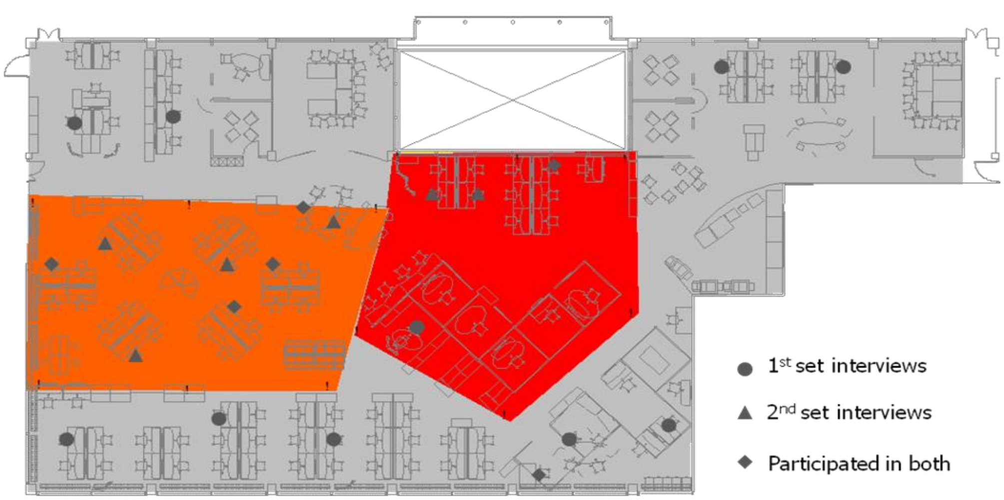


Figure 5.8 Distribution of interviewees in the floorplan.

Moreover, specific questions were added that related a) to the visual display with the live location data, and b) to the visual awareness of the deployment due to the attachment of the sensor network to the department's ceiling. The sample was distributed across the office. See figure 5.9. The first set of interviews was chosen as a cross section of individuals spread across the office, across all units including the three departments. The second was composed by a cross section of the sub-group of 51 individuals carrying the UWB tags. Five individuals were in both groups. In all that follows, the names of the interviewees have been changed to preserve anonymity. Beside the alias, the initials of the department to which they belong are included. See annex E for templates, a list of interviewees and their profiles. The results are shown in Chapter 6.

Limitations

The limitations relate very much to those described for the participant observation technique. Regarding the time issue, the researcher would have liked to conduct further follow - on interviews, later in the year, but it was not possible, for access was not granted.

Analysis

Interviews were used to understand staff attitudes to the technology, their understanding of the technology and how their attitudes towards it changed through time. The researcher produced immediately after the interviews condensed accounts in order to record the main topics that interviewees emphasized. The full interviews were transcribed by an on-line professional service (see annex E). The analysis was conducted using N-Vivo software as follows. Starting with the propositions or high level assumptions (see Chapter 4), the text was coded looking for issues related to them in an iterative process going from, initially many diverse issues, to grouping them into wider categories until an interpretation or answer to the propositions was constructed.

In order to eliminate experimental bias, an effort not to make assumptions about how these issues would evolve (positively or negatively), neither to predict the results or the answers to the questions, was made. This approach facilitates a research process that unfolds and evolves rather than being pre-structured (and therefore constrained), an important criterion given the relative lack of existing research in this area (Spradley, 1979, 1980; Spradley and McCurdy, 1972).

The propositions were used to initiate the study but were developed as the research proceeded. Once the data were collected, analysed and compared with the initial propositions, the propositions were revised as necessary.

5.6.6 Depthmap

Data Collection

Depthmap creates a graph and visualises the visible connections of a selection of points across a space. With this visibility graph measures of various features of the graph can be taken. Initially, plans of the A2 room were collected in drawing exchange format (DXF) using AutoCAD.

Limitations

Space syntax techniques have been criticised for their limitations inside buildings. Because activity and space use are regulated by different forces, their analyses haven't been able to predict movement and behaviour as well as in urban environments. This thesis joins the argument that some of their techniques can help to identify spatial variables, such as visual fields, and visualise them in a rigorous way which can be quantified and used to understand the social adequacy of a space (Peponis and Wineman, 2002; Turner, 2003).

Analysis

Once the visibility graph is made, the measures that are going to be tested are those that have been found to have related to interaction and privacy behaviours, namely visibility integration and control (Rashid et al., 2005, 2006; Alalouch and Aspinall, 2007). This analysis contrasted with the results obtained with both the automated and the manual methods attempts to assess the advantages and limitations of each approach and to understand the effects spatial features and attributes have on interpersonal dynamics.

5.7 Participants' involvement and consent

Annex A, presenting the communication records, includes the different e-mails and the presentation given to the pilot participants by the project champion, and also those e-mails that refer specifically about the researcher role in it. This collection of documents reflects the formal aspects of the communication between the company, the participants and the researcher. More informal communication – via e-mail, telephone and face-to-face – was conducted between April and July 2005, but these have not been included in the appendix.

It is important to mention that the researcher did not have direct responsibility for involving the participants in the pilot. Involvement was arranged through the contact in the company, the project champion. The only thing the researcher was allowed to do, once access to the building was granted, was to arrange the interviews in person. Therefore, there was no formal request for participation to individuals and no formal consent forms to be signed. As was mentioned in the previous chapter, obtaining access to the whole pilot was done after negotiation and signature of a non disclosure agreement (NDA) between UCL and Nationwide Building Society. In consultation with UCL Ethics Committee, Mrs. R.H. Cummings, Records Manager and Data Protection Officer, was informed of the situation and confirmed the project did not need to be registered on the UCL Data protection registration database, for the research was not developed in UCL premises.

5.8 Confidentiality of Data set

Given the special nature of this project, and having signed the NDA with Nationwide, it was agreed that the name of the company could be used to disseminate the results of my research, that the real name of the Head of Research as well as the name of the company pilot could be quoted, but the names of the participants have been changed to preserve anonymity. The location data have no specific attachment to individuals for the tags distributed to the 51 participants were handed in at the end of the day and put in a bowl. The following morning, participants would pick up a new tag to be handed in at the end of the day, and so the process was repeated every day until the end of the pilot. The data coming from the space observations has been aggregated and analysed anonymously.

5.9 Next steps

The next five chapters present the results of the case study at different levels (see figure 5.10). Chapter 6 examines perceptions and attitudes towards the technology deployment. Chapter 7 focuses on the spatial and temporal aspects of space use and interaction patterns investigated through manual and other methods and chapter 8 does the same using the new automated method developed in the thesis. Chapter 9 will present a comparison of both types of methods based on these analyses and discuss the theoretical implications of the findings combined.

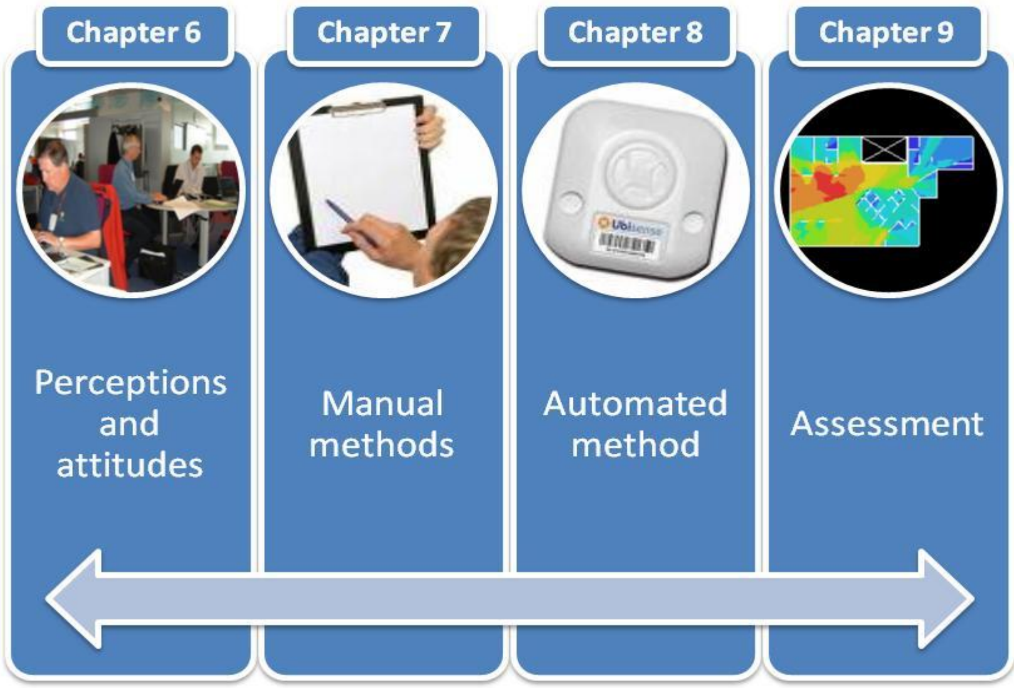


Figure 5.9 Next steps summary.

Key Points

- The Nationwide Building Society Headquarters is the case study site.
- Nationwide Smart Space pilot explored the potential of different location technologies to improve the use of their buildings.
- The deployment of an UWB location tracking system in one of the building offices became the backbone of the case study.
- The technology was provided by Ubisense Ltd.
- 111 workers, 51 of those wearing Ubisense tags, took part on the study.
- A combination of qualitative and quantitative data collection strategies and tools were used.
- The case study lasted for 8 weeks.
- For 6 of those weeks the Ubisense system was in place.

Notes

1 Quotation and general information obtained from an internal Nationwide report.

2 Nationwide defines itself as a modern mutual building society. Their sole purpose is to provide members with the best possible value in personal finance services. Putting their members first is the main priority in their internal communications campaign, PRIDE, launched in February 2002. PRIDE stands for _P_utting members first; _R_ising to the challenge; _I_nspiring confidence; _D_eliver best value; _E_xceeding expectation. It lasted for five years.

3 Data from an internal Nationwide report.

4 This section is based in a series of documents produced by Ubisense Ltd. for their client Nationwide

building Society and conversations of the author with the Head of Research and the Ubisense consultants in charge of the deployment.

5 CISCO had a similar deployment in the US at the time. The author did not get the chance to access it. Nothing has been published as to the author's knowledge.

6 Radiation coming from either of the two tags was significantly lower than that emitted from a mobile phone.

7 It is noticeable that the data sets gathered have limitations that may inhibit the transferability of the findings, as it was noted in Chapter 4. But the specific context of the case study has particular constraints that are important to acknowledge, manage and work around, for they might have a more direct impact on the findings than initially foreseen. The limitations described do not severely compromise the data, though it is important to remain aware of the issues highlighted for the remainder of this thesis and in the case of considering future similar research in a different organisation.

8 While this case study does a comparative study of activity patters in the office before and after the deployment and uses methods widely used in POEs it cannot be strictly considered one, for the objectives of this part of the investigation are focused on detect changes on behavior more that to conduct a building evaluation, either measuring the success of the space design or feeding into the organisation's workplace design or other strategies (BCO, 2007: 15).

9 Together, the total amount of time spent at the office case study conducting participant observation (8 weeks), and the 6 weeks worth of location tracking data, although cannot be considered longitudinal, can be considered representative of a year's work. Only the location dataset amounts to 11.5% of yearly time worked.

10 Apart from those 111 workers it is highly possible that there were visitors from other departments. This was impossible to discern by the observer.

Chapter Six:
Workers' attitudes towards the technology deployment

Abstract

Beyond the detection and segmentation of interaction dynamics, the counting of activities and their repetition, and beyond perceived and reported behaviour, this chapter pushes forward the thesis narrative by presenting in-depth insights into the most intangible aspects of the technology deployment. Starting with a discussion of the physical aspects of the deployment and the technical, spatial and social challenges that were posed to both Nationwide and the technology company, the chapter provides an account of the participants' perceptions and attitudes towards the location tracking system, from their point of view. Specific issues of communication, time, privacy and culture are discussed, and a commentary of the key points including further research paths opened by this part of the study are displayed. The interviews conducted are enhanced by participant observation, which allows a complex socio spatial and technical reality to be portrayed in detail.

6.1 Introduction

The two next chapters are dedicated to understanding different interaction behaviours in the office site. The objective is to provide a picture of the socio spatial environment within which the technology was deployed. In this section the focus lies on understanding and discussing the more qualitative aspects of the use of the technology and its deployment in an office environment. The practical potential for increasing understanding of interaction in the workplace through the analysis of location tracking data depends critically on the acceptance by staff of these location tracking technologies (Roussos and Moussouri, 2004; Konomi and Roussos, 2007; Poole et al., 2008). The chapter starts with a description of the practical issues that the deployment highlighted; follows with a discussion on the extent to which participants understood the pilot, and how this understanding was built; privacy issues are covered and the concept of "collective imaginaries" introduced, and the role of trust in the acceptance of the pilot is presented. Finally, a summary of findings regarding both the results of the pilot as conceived by the organisation and the results of the qualitative investigation are included.[1]

6.2 Insights into the tangible aspects of the deployment

As discussed in Chapter 4, the actual performance of the system deployed in tracking staff was poorer than predicted. The disparity was due to issues related to the reliability and accuracy of the system and to the management and interpretation of the location data obtained.

Further to issues discussed in Chapter 4, the system's reliability was compromised due to a software problem in the basic tracking that the technology company consultants had not encountered in previous deployments. Unfortunately, this problem was never completely resolved during the pilot. The second factor contributing to the lower than expected accuracy of the readings was due to the prevalence of metal in the office environment. The metal influenced signal propagation which introduced errors in locating the tags. Unfortunately it was not possible to resolve this problem by adding additional sensors and changing sensor positions.

Finally, the difficulty of managing and interpreting the data came as an unexpected surprise for the Nationwide team responsible for the pilot deployment. Location data were filtered and inputted into an Excel spreadsheet but there was no clear link between the rich granular data and the organisation's need for sophisticated occupancy and utilisation analysis. The development of further software applications to provide this analysis was not conducted in either the context of the pilot nor outside it.

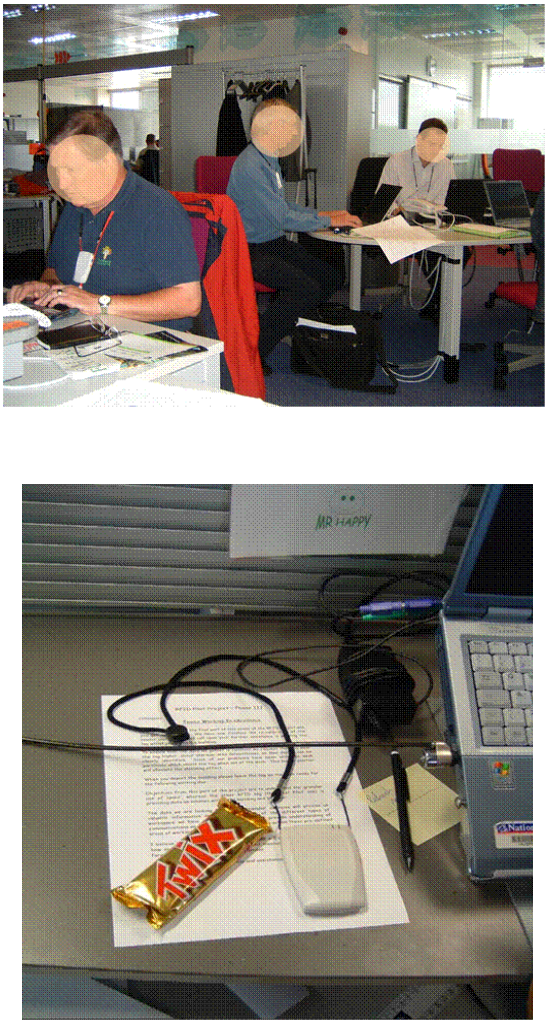


Figure 6.1a, 6.b Two examples of different ways of wearing the tag.

Attempts were made to overcome the accuracy problems resulting from signal interference by changing the way that users wore the tags. For the system to work effectively, the tags had to be worn in such a way as to ensure that no metal obstructed the line-of-sight between tag and sensor. Whilst staff were quite used to carrying swipe cards to access the building, these did not need to be worn in any particular manner. For the Ubisense system tags to work, however, they had to be worn high on the body, typically hanging close around the neck. The majority of staff found this cumbersome and irritating since the Ubitags weighed some 66 grams. As a result, staff frequently removed them, placing them on the desk while working and then failing to pick them up when moving around the office or, alternatively, placing them in their pockets or bags and forgetting about them (see Figure 6.1 and 2).

One of the interviewees summarised user attitudes to the tags, stating: "The mechanics of actually wearing it was inconvenient….. Especially on top of the fact that we've also got another extra tag at the moment anyway. So we're wandering around with three things around our necks where normally there'd be one" Mark (PS).

Other members of staff commented that "I was pretty good about wearing it" - Anna (RS), this suggested that wearing the tags never become 'normal' and was viewed as an obligation. Clearly, the temporary nature of the deployment contributed to the willingness of staff to accept the inconvenience, as is explained later in detail. Despite this, after two weeks, few staff were wearing the tags as intended: hanging from the neck and in open view, facing the ceiling and clear of any obstacles. This, combined with the fact that the desks' partitions were made out of metal, resulted in few and inaccurate readings.

To obtain better readings, attempts were made to change staff behaviour in the third week of the deployment. This proved to be difficult. The project champion was able to make staff wear the tags correctly for a few days, but in the end they reverted to wearing tags in the way that best suited their habits. When the tag became a nuisance they simply dropped it. There were very few readings in the last days of the pilot as a result of this behaviour.

6.3 Participants' understanding of the deployment: The role of the Communication Strategy

User understanding of the pilot was largely a result of the communication strategy. Users held conflicting perceptions on the success of the communication strategy. A small majority of staff believed that the communication strategy had been successful. "I actually thought the communication was quite good and that it was communicated clearly" - Gwen (PS). On the other hand, a significant minority were critical, complaining about a lack of communication.

The informants' understanding of the deployment in terms of objectives proved good and there was a common agreement on the terms used to describe it: *movement, space utilisation, granular, granularity, workspace utilisation, better working environment*. This is a reflection of the internal communication campaign accompanying the project that helped to develop a shared understanding of the pilot aims. Understanding was not uniform, however, one member of staff commented: "It is difficult to know what you are trying to get out the project" - Anna (RS).

Despite the efforts put into communication, staff failed to understand the project scope and physical extent of the pilot. None of the respondents, apart from individuals working very closely on the deployment, could explain the scope of the tracking, in which areas it was happening and in which it was not. When asked about boundaries, a typical response was "I have got no idea. I don't know what area is actually being measured" Shaun (PS). Moreover, this happened despite the fact that the sensor network was hanging from the ceiling in open view with the sensor boxes pointing inwards (see Figure 6.2)

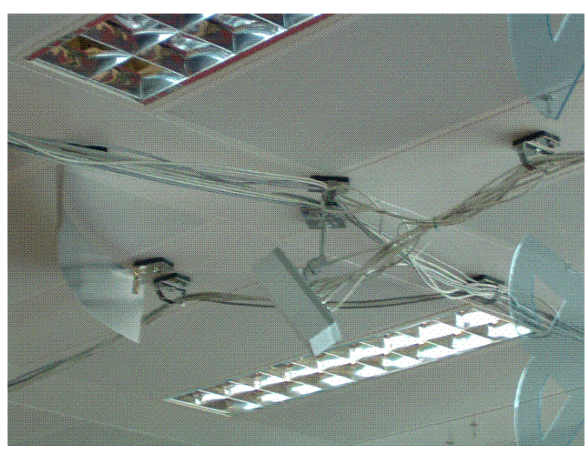


Figure 6.2 Picture of the actual deployment.

Users generally did not understand what the data was being used fo, nor did they understand how the raw data was being used to analyse space utilisation. Although the communication process was used to diffuse concerns about data protection, this aspect of the pilot was not covered in the communication plan. As it will be observed in the forthcoming section on privacy, misconceptions about the way data was being used did lead to concerns among staff.

A note must be made at this stage on the temporary nature of the deployment. Acceptance of the pilot was significantly eased by the fact that it was just a trial and was provisional. "I had no real problem with it. I understand this was just a trial, wasn't it?" Carol (RS). The fact that the deployment was temporary and brief meant that it was not perceived as genuine. "So, you know, if you did it for real […]"Robert (PS). This fact hugely influences concerns about privacy and other attitudes towards the technology.

6.4 On the mystification of the spatio-technical scope of the location tracking system: privacy issues and intrusion fears.

The real-time display in the centre of the pilot area (see figure 5.5 and 5.6 in Chapter 5), provided an element of openness regarding the data being collected by the system, by allowing the staff to see exactly what data was being gathered. Staff did however, have some concerns about privacy, despite the communication plan and the real-time display. Participants reacted to the display in two ways. One set of respondents looked at it, found it interesting and tried to search for themselves on the display but could not make out where they were and if they were moving and therefore lost interest; this group also found the process open, a feature that showed there was "nothing to hide" Gwen (PS). The other set did not look at it, lacked interest in it and had a general feeling that it was "a PR exercise" Matthew (RS). This last behaviour has also been noted in pervasive computing deployments in real environments (Konomi and Roussos, 2007).

Staff concerns about privacy appear to be strongly influenced by their perceptions of the systems capabilities and operation. As noted before, despite the efforts put into communication the majority of staff beliefs regarding the system were at variance with the reality. In reality, there is a difference between location data being gathered by a system and the system providing the capability to extract information about individual's behaviour. The Ubisense system did not provide this second capability but staff did have concerns about their privacy being invaded by being observed all the time at work.

There was a high degree of uniformity among participants in their misunderstanding of this aspect of the pilot. None of the respondents, apart from those working very closely on the deployment, could even explain the scope of the tracking, in which areas it was happening and in which it was not.

The uniformity of staff perceptions regarding how they were being tracked could be understood using the concept of 'collective imaginaries'[2] built by the informants around the technology deployment. As a result of the experience of the deployment, informants developed a thought structure that combined rumour and reason that resulted in the mystification of the spatial and technical scope of the technology and the manipulation of the location data obtained.

These collective imaginaries are constructed within social groups exposed to the same experience and information, and take the form of a shared belief. Discussions and conversations between group members may serve only to strengthen and entrench this shared impression. With regard to the staff at Nationwide, a majority thought that they were being tracked around the whole building, even into the toilets, and that "someone" was able to know exactly what they were doing at all times and with whom. It is plausible that the collective imaginaries that developed were influenced by the national context, with considerable media attention devoted to debates on identity cards, CCTV and perhaps in part by reality television shows such as Big Brother (Big Brother, 2000)[3]. The shared organisational context and culture are also likely to have had an influence on these perceptions.

Again, it should be observed that not all staff shared the collective belief regarding the extent to which the system was being used to monitor individual behaviour. However, it may be pertinent to note that the only staff member explicitly to reject this concern (stating "it's not being used to track you around the building" Laura (PS), worked in the Property Services group with a responsibility for security.

6.5 Workers' attitudes: building trust through the organisational culture

As a building society, Nationwide places considerable emphasis on the creation of a common organisational culture. This is reflected in the strong branding around the building. Large numbers of images and messages are displayed proclaiming the organisation' values, the degree to which they care about their staff, advertising the exhibits they organise every week, the superb and always popular canteen, the Starbucks cafe etc.

The interviewees' responses also support the fact that there is a strong organisational culture and suggest that it had a positive impact on staff attitudes to the deployment. This factor has been found in other research to be important to the successful deployment of a pervasive computing system (Konomi and Roussos, 2007). Key aspects of the influence of this culture relate to trust and to pride in the organisation. The general perception that Nationwide is a fair and open organisation appears to have been transferred into attitudes to the deployment. Staff explicitly cited their trust in the organisation to explain their lack of concern of the potential for the technology to be used to monitor them. Responses to questions about the use of the data from the pilot such as "no, I think Nationwide is a fair organisation" Andrew (PS), were typical.

Responses also suggest pride in being part of a forward-thinking company. The deployment of an advanced technology could be seen to fit with staff perceptions about their organisation and in itself became a focus for pride in the company. "There doesn't seem to be anybody else sort of doing this work […] this kind of smart work environment that we've got here because we're kind of the first department to have this environment" Shaun (PS), and "Nationwide sets themselves as a, you know, benchmark for other people, to come in and have a look at what we're doing. So we're at the forefront, which is good" Albert (PS).

While a strong organisational culture exists in Nationwide, it would be wrong to depict it as all-pervading or perhaps totalitarian. The organisational culture is for most, if not all staff, only one of a number of cultures within which they are immersed. Their response and commitment to the organisational culture is potentially mediated by the influence of national, local, religious and class cultures.

Underneath the widespread acceptance of the organisational values and ethos, however, a current of cynicism was apparent, suggesting that the overt organisational culture, while powerful is not ubiquitous. Surreptitious reluctance and even bitterness for making participation in the project ostensibly voluntary while making it clear that those who did not take part were acting against the organisational modus operandi, ran strongly in some interviews. However, dissention from the accepted ethos was rarely explicitly stated, rather being conveyed through tone of voice, expression and body language. Clearly, no organisation such as Nationwide can ever maintain, nor, in all likelihood, would it seek to maintain, an all-pervading influence on the views and perceptions of individual staff.

6.6 Summary of findings

6.6.1 Challenges posed by the real environment to the location tracking system

The outcomes of the pilot as conceived by Nationwide were mixed. Installation was more time consuming and intrusive than anticipated and the system never delivered the promised results. Two related issues caused these problems. Firstly, the pervasive presence of metal in the environment interfered with the transmission of the signals. Secondly, users' preferences on how tags were actually worn and carried, conflicted with the operational requirements of the system.

Metal partitioning is extremely common in office environments and its presence should have been foreseen by the technology company. Developing technologies away from the real word context in which they will be deployed is always likely to result in these kinds of problems.

Users' habits and ingrained behaviours are extremely hard to change. Technologies that require these changes are unlikely to succeed in the absence of a strong sense of perceived benefit. However, the data gathered by the system can provide clear insights into how buildings are actually used through time and offers real potential for improving our understanding of human behaviour in office environments. If these potential benefits are to be realised, more sophisticated applications will be required to translate the raw location data into useful information, which is the main objective of this thesis.The deployment of a location system in this office environment brought to light the "perfect system versus degraded environment" dilemma. There is a fundamental difference between setting up a technology experiment in a controlled environment and taking it into real life. As it has been pointed out, real environments are complex and unstable for a combination of spatial and social reasons, amongst others. The majority of computer scientists tend to think about "perfect systems" that work very well in a "perfect environment" in which those two variables, space and people, are controlled. When faced with a real environment this is perceived as degraded because does not provide the same controlled and perfect socio spatial environment. In this case, the technology provider had made assumptions, given the performance of the system in controlled environments they knew well – such as their own office in Cambridge – that do not apply to all buildings or organisations. Consequently, expectation mismatches and disappointment potentially follow the deployment of the system. This point has been noted in similar research exploring deployment of pervasive systems in real environments (Konomi and Roussos, 2007). It is our contention as a result of the experiments conducted at Nationwide that this approach is naive. Real deployments, and, in particular, the engagement of real stakeholders, should become requirements of the test environment in which the claims made for such systems are validated.

6.6.2 People's findings: a summary of key issues

Given the efforts put into communicating with staff it is perhaps surprising to discover how poorly they understood the pilot. This lack of understanding was not, however, uniform. Unsurprisingly, those most closely involved had the most accurate understanding. More significantly, staff from Property Services who had no direct involvement in the pilot generally had a better understanding of its objectives, scope and extent. This may be due to closer informal contact with other staff that were directly involved and hence had a better understanding of it. It may also be due, in part, to the fact that it was widely understood that this pilot would benefit their group, even if the nature of the benefit was poorly understood.

A number of factors can explain the relative failure of the communication strategy. While presentations were given to staff and information was transmitted through emails and other means, these communications were competing for the limited attention that busy staff have with other communications directly relating to their jobs and roles. In the face of this competition, staff with no attachment to the pilot simply do not appear to have taken the time to read and understand the communications sent to them. A recommendation for future research and future deployments would be to have more face-to-face communication, informal talks and information sessions, in small groups with a proactive approach, in order to obtain the engagement of the participants. In the case reported here, only 1 out of 28 interviewees was present at the presentation given at the beginning of the project. Lack of engagement, interest or sense of involvement can largely be explained by the fact that the system provided no tangible benefits to staff outside the Property Services group. The ability of these systems to offer tangible benefits to all users is likely to be an important factor in staff's understanding and ultimately acceptance of similar location tracking systems.

A successful, invasive office technology must provide tangible and immediate benefits to the workers involved (Poole et al., 2008). That holds for all types of systems, whether collaborative or not, synchronous or asynchronous. Thus, the deployment of a location tracking system in an office environment should provide a set of benefits and such benefits are usually perceived through functionalities of a system and their direct impact on the personal working experience of an individual. In this pilot only one such direct functionality existed - the stand alone PC acting as a 3D visual display of the real tracked movement. Nobody saw this as a benefit. Belonging is an influential variable on the perception of benefits. Moreover, given the personal sensitivities involved, good communication is key to understanding the data obtained and allows for its effective interpretation and manipulation. Recommendations for the design of a deployment should take into account these findings and adopt a multilevel deployment strategy involving, at the very least, the social, spatial, technological and temporal issues discussed within this chapter.

Issues of privacy, transparency and control are influenced by collective imaginaries that mystify the technology, make it obscure and mysterious, and increase fears of privacy invasion, lack of transparency over the data and losing control over the manipulation and post processing of the data. The influence diminishes, and therefore objective understanding of the deployment improves if one is involved in the project and trust in the organisation is solid. However, it would be a mistake to assume that outside the protective environment afforded by the company one would see the same reactions to privacy invading measures of the individuals involved.

Key Points

- Trust in an organisation's management is essential for the acceptance of the technology.
- The temporary nature of the deployment considerably eased its acceptance by staff.
- The lack of immediate personal benefit negatively affects the perception of usefulness of the deployment.
- Workers perceptions on the general scope and objectives of the technology were influenced by sources external to the organisation itself, such as the media.
- Wearing the tag was perceived as a nuisance, but this perception diminished through time, probably influenced by the temporary nature of the deployment.
- Individuals developed behaviours around wearing the tag that best suited their habits, ignoring formal efforts for staff wearing it efficiently.

Notes

1 A book chapter summarizing the more qualitative aspects of the study of the deployment was published before the submission of the thesis (Lopez de Vallejo et al., 2008).

2 Academics suggest that group and individual action emerges from collective imaginary, a kind of cultural conditioning that generates the context in which human actions gain sense. Collective imaginary acts as a filter for new information, being the lens through which people perceive the world. Collective imaginary is constructed through narratives that convey sense and therefore help people to understand novelties by including them in a series of meaningful events (Mordini, 2007).

3 A reality television show is a genre of television programming that presents purportedly unscripted dramatic or humorous situations, documents actual events, and usually features ordinary people instead of professional actors (Hill, 2005). Big Brother is probably the best known documentary - style show in the world with different versions produced in many countries around the globe. In each series, a group of people live together in the Big Brother House, isolated from the outside world but continuously watched by television cameras. The show's name comes from George Orwell's 1949 novel *Nineteen Eighty-Four*.

Chapter Seven:
Measuring physical interaction spatio-temporal features with manual and other methods

Abstract

Perceptions and attitudes towards the technology deployment and the use of technology, serve as a qualitative background against which observed and self-reported patterns of spatial and temporal behaviour overlie and contrast. This chapter describes interaction patterns, observed behaviours of use of space and perceived formal interaction cycles studied using manual and other methods. It presents aggregated findings regarding the use of space and different behavioural activities observed through time, as well as the results of a questionnaire where issues of work style and perceived interaction routines and places are explored. The layout of the office where the case study was conducted is analysed using Visibility Graph Analysis (VGA), a space syntax technique which is used in two ways here: to talk about the office features and their effects on visibility and to discuss the observations and questionnaire findings related to specific layout properties – visibility integration control and controllability. The results of the combined analysis of behavioural patterns in space and through time using manual methods are contrasted with the hypotheses testing the automated method potential formulated in Chapter 4. These lay the ground for further comparison of both manual and other and automated techniques in Chapter 9.

7.1 Introduction

Evidence provided in Chapters 2 and 3 reveals that an understanding of how people use space, interact with others and with the built environment through time, is largely of a tacit nature and remains untested by empirical verification. Partially successful attempts to test it, have been made in different disciplines which highlight that it is extremely challenging to pin down the detail of the pervasive nature of interaction dynamics through time in the workplace. The spatial and temporal aspects influencing interpersonal dynamics have been explained in detail in previous chapters. Also, it has been argued in Chapter 4 that this detail can potentially be portrayed using highly precise location data. This specific point will be tested in the following chapter. Throughout this section of the thesis the purpose is to describe some of the social and spatial circumstances surrounding the technology deployment in the case study, using widespread methods and tools as described in Chapter 5. It is particularly important to detect differences in behaviour before and after the technology deployment to further discuss the qualitative analysis and the propositions set up in Chapter 4. In addition, the results of the analysis serve to test the hypotheses listed in that same chapter, contrasting the information obtained with these manual and space syntax methods against them. In Chapter 8 the same will be done with the automated method. In Chapter 9, a comparison between the two sets of results will highlight the advantages and the limitations of each approach and the potential contributions of the automated method to the state-of-the-art thinking in a number of academic areas.

This chapter therefore presents the combined results of space observations, questionnaire, participant observation and VGA analysis in three main sections. The first section describes patterns of activities and space use, and relates to hypotheses 1 and 3. Then next section portrays observed and reported temporal aspects of interaction behaviour, which relate to hypothesis 2. The final section presents results from a spatial perspective, focusing on the office features and visibility affordances and their relation with behaviour observed through time, which helps in testing hypotheses 4 and 5.

It must be remembered that the data analysed in this section comes both from observations conducted before and after the technology deployment and a survey[i]. The introduction of the system in the workplace was expected to have an effect on spatial behaviour, as it is discussed in the following sections. The author's underlying assumption was that workplace activity was going to increase perhaps due to a collective response to the perception of being monitored.

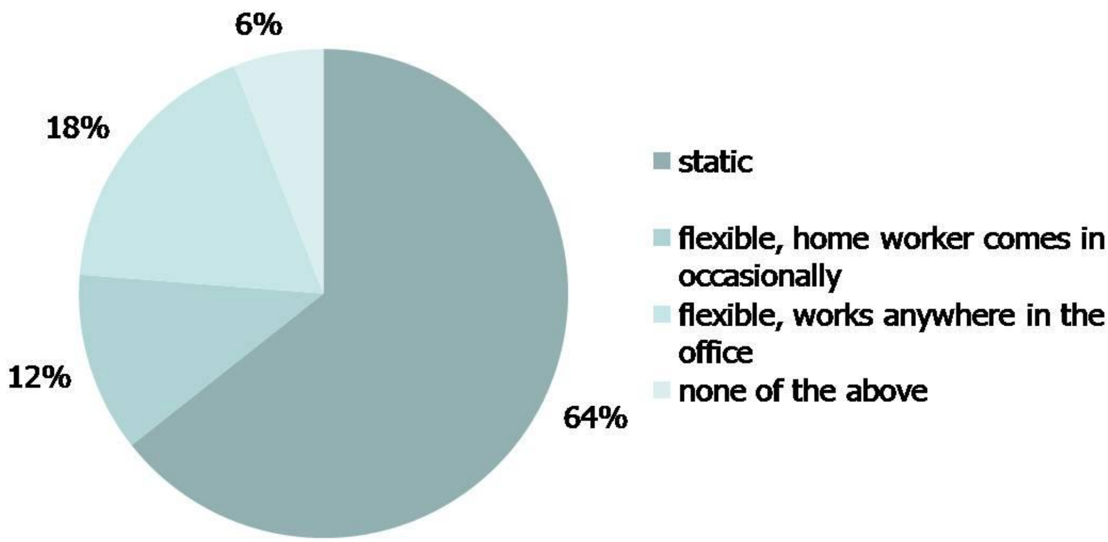


Figure 7.1 Distribution of types of work style in the office site.

It is also worth mentioning that the sample population varies with tool or technique used to gather data. Observations of space use involve 111 workers plus visitors, and the survey, also involving 111 workers, got 71 answers (64% answer rate). These 111 workers belonged to three departments (Retail Strategy and Planning, Property Services and Legal Compliance)

located in the second floor (A2 room), of the main Nationwide building in Swindon, UK. For a summary of tools, types of data gathered, participant numbers and timeline please refer to Table 5.7 in Chapter 5; for details on data analysis see annex I.

Before presenting the results of the analysis, a brief portrayal of workforce demographics and their work styles is needed to set the context. Results of the survey reveal that the group of people occupying the A2 room at the time of the deployment was predominantly male (60%), middle aged (43% fell into the 40-50 age group), and employed long-term by the company. 63% of the respondents have worked for Nationwide for more than five years, which is an indicator of organisational acculturation or assimilation of the company culture and values. Workdays are typically of the 9 to 5 type with flexible hours, mainly used by female workers. A third of the workforce has some sort of flexible working style arrangement.

The majority (64%) of the respondents identify themselves as static workers; a third (30%) are flexible workers, 18% work anywhere in the office, and 12% are home workers who come in occasionally. See figure 7.1.

Workdays and work styles are predetermined by the organisational structure and the role played. Only 4 of the respondents do not see themselves in any of those categories, perhaps due to the presence of external contractors involved in ongoing projects and based at the office site.

7.2 Patterns of interaction behaviour and work activities

Interaction behaviour data is based on a) self-reports of visits made to other departments in the same building; b) accounts of held and attended meetings and c) types of interaction behaviour and work activities observed - these can be categorised as informal meetings in the office and general work activities: sitting, standing, talking and walking.

Visits to other departments account for intra-organisational interaction with other groups, which it was identified in Chapter 2 as an indicator of knowledge transfer and a key element of organisational innovation. Asking workers to differentiate where and how often they both hold and attend to meetings, is meant to explore some of the subtle differences between proactive (holding) and passive (attending) meeting behaviour. Finally, manually counting the number of people present in an office and the activities performed provides evidence for activity patterns in the office environment. Also, in order to measure a possible change of behaviour after the introduction of the location tracking system in the office, two sets of observations were made: before the deployment and after it was installed and in use.

Respondents reported a roughly equal distribution of meeting behaviour: 49% of held meetings versus 51% of attended meetings (see table 7.1). This indicates the autonomy that workers have in proactively holding meetings. This behaviour is also reflected in the number of workers who reported visiting other departments (72%). Nationwide promoted this attitude for this particular department: it was legitimate to find others to talk informally.

Movement was used in this study as a tool to measure the effect of the deployment on the most basic of physical routines: the amount of walking done before and after the technology was functioning. Whereas movement in an office environment is not a good predictor of face-to-face interaction, variations in the total number of people seen moving in this space before and after the deployment might indicate the volume of people present and therefore visible co-presence. The effects of visibility in observed behavioural patterns are explored in section 7.4.

Incidentally, total movement after the deployment increased by 13% (see figure 7. 2). There were more people in the office after the deployment, which suggests co- presence was higher. This may have been provoked by the deployment of the location tracking system and fears of being constantly monitored. Given that the results of the interviews show how little understanding of the scope of the technology participants had, it can be argued this was probably a collective perception that influenced the collective behaviour of the staff working in the A2 room. Observations of workers' behaviour during the case study period show how all work activity also increased after the deployment, corroborating this point. Perhaps people felt they had to be more present and more visible to be perceived as active and useful by their manager (see figures 7.3 and 7.4). A more detailed analysis of activities further supports this idea, which links to hypotheses 1 and 4. The proportion of workers observed talking to others, mainly in informal 2 to 3 people face-to-face interactions, increased from 65% to 77% after the deployment. In addition, the percentage of people talking on the phone decreased after the deployment (35% before vs. 23% after). See figures 7.5 and 7.6 for details. Also, the A2 office houses two call centres, therefore although the amount of people on the phone will always be high, the amount of observed behaviour definitely decreased after the deployment. For this particular situation and after the deployment of the location tracking system, people apparently not only thought that being present was important, also that being seen talking to others was behaviour to openly demonstrate and being on the phone a behaviour to avoid. Perhaps workers in this context perceive that being present, active and engaged in face-to-face conversation more than on the phone might demonstrate an image of being focused and effective, and acted accordingly, interacting.

On the other hand, it is necessary to point out that these particular percentages are relevant to prove the previous point, but are not considered significant by the author, for they may have been caused by the type of workload on that particular week. That is the reason why long term data are needed to identify the real cause of these changes.

7.3 Temporal aspects of behaviour

The temporal analysis of behaviour focuses on understanding how individuals spend their time at work, and how different work activities fluctuate through time. Interaction data based on self–reports provides information on visits to other departments, and frequency of meetings held and attended daily, weekly and monthly. The aim is to understand everyday behaviour, weekly routines and monthly, or more irregular, meeting routines. Regularity may be key to the development of interpersonal relationships (Altman et al., 1981), although there is little empirical evidence to support this.

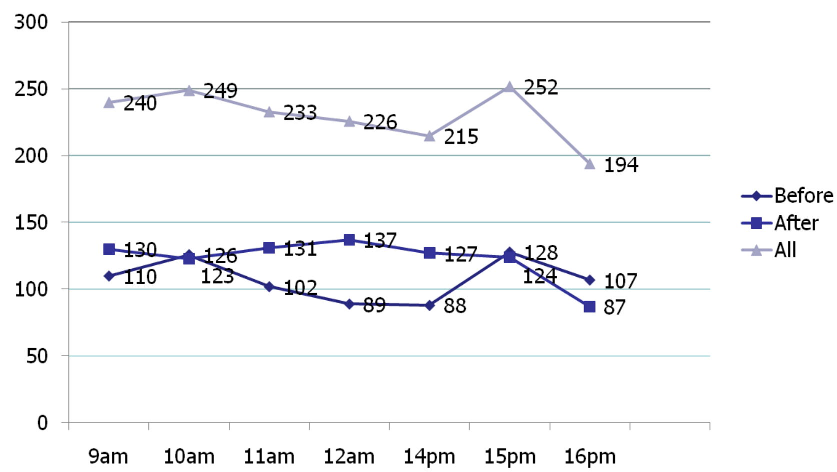


Figure 7.2 Before, After and All movement by time of day

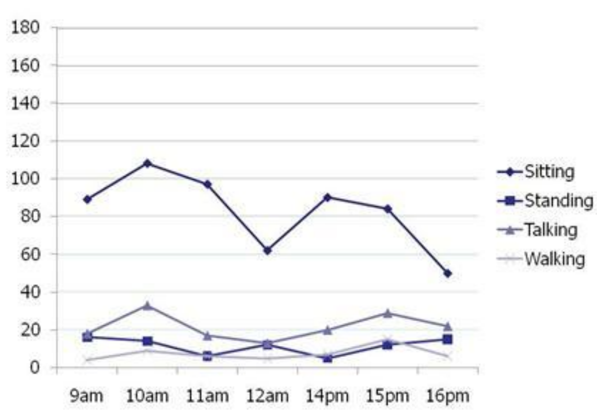


Figure 7.3 Before All Activities by time of day

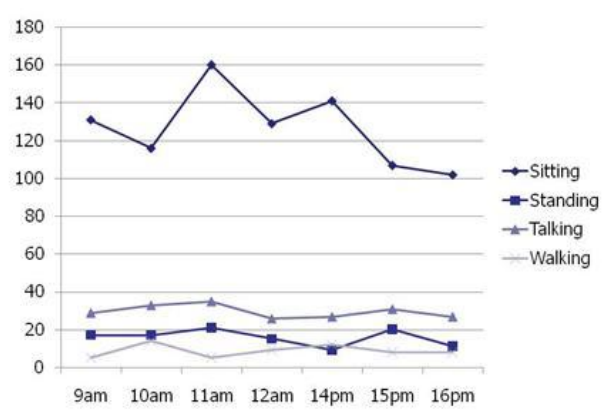


Figure 7.4 After All Activities by time of day

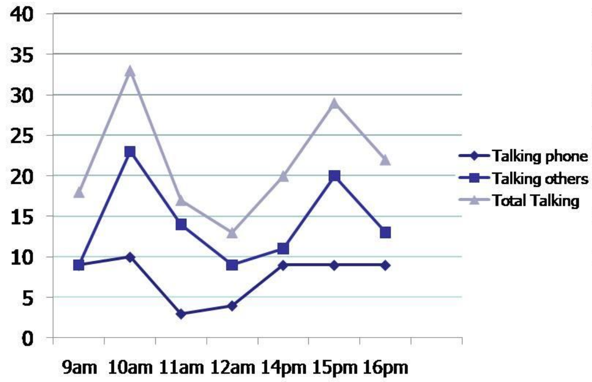


Figure 7.5 Before deployment, number of participants talking on the phone vs. talking to others, per hour

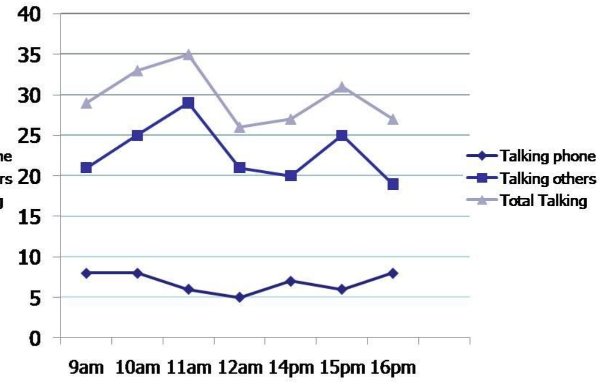


Figure 7.6 After deployment; number of participants talking on the phone vs. talking to others, per hour

	Daily	%	Weekly	%	Monthly	%	Total	%
Hold	42	**16**	150	**57**	69	**27**	261	***49***
Attend	33	**12**	159	**59**	78	**29**	270	***51***
Total	75	***14***	309	***58***	147	***28***	531	**100**

Table 7.1 Reported volume and frequency of meetings held and attended.

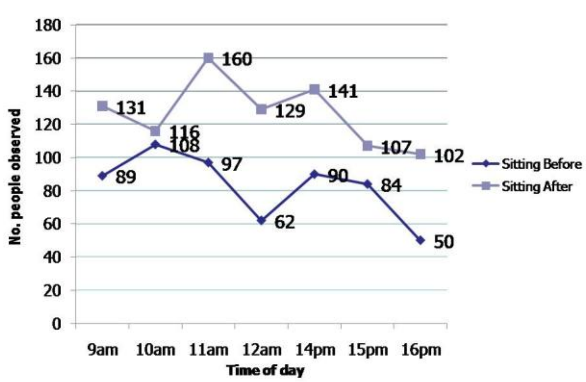


Figure 7.7 Total no. of people observed Sitting before and after the deployment by time of day

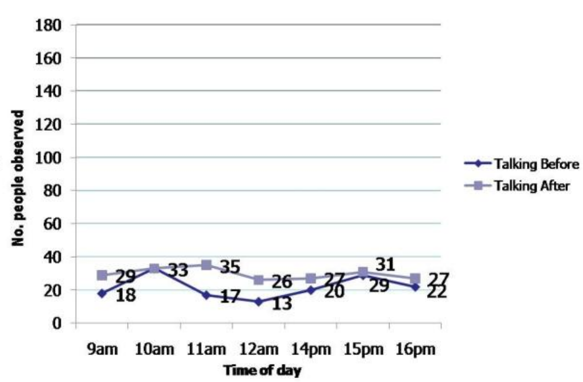


Figure 7.8 Total no. of people observed talking before and after the deployment by time of day

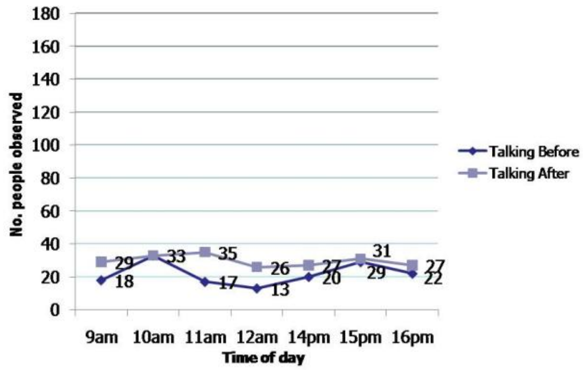


Figure 7.9 Total no. of people observed standing before and after the deployment by time of day

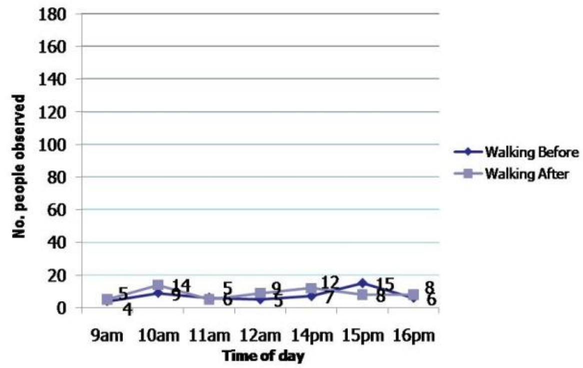


Figure 7.10 Total no. of people observed walking before and after the deployment by time of day

In this particular case study, the temporal framework used in the manual analysis includes both the period before and the period after the deployment. For each period the unit of analysis is the working day, divided into hours. This approach provides another perspective on the organisation of work activities throughout the working day, and captures changes in behaviour through time.

As has been mentioned before, a good proportion of the respondents have an active relationship with other groups located in the same building (72% visit other departments regularly). The length of time that employees have worked for the company influences their contact with other departments; those who have worked for the organisation less than a year are more likely to report no contact at all with other departments. Time worked for the company can be cross tabulated with unit and type of worker, but these variables do not seem to be influencing contact where participants have been working in the organisation for less than a year. It would have been useful to have examined these results in conjunction with each subject's role in the company, to determine the extent to which their position in the organisational structure affected subjects' contact with other departments, but this particular question was not included in the survey.

With regard to the volume of meetings reported, respondents seem to have a balance between the total number of meetings held and attended (analysed by frequency). These results reveal that people claimed to hold more meetings on a daily basis than they attended, whereas on a weekly and monthly basis, the perception was reversed. See table 7.1. This might reveal that while workers have autonomy for seeking out opportunities to meet others in the workplace on an everyday basis, the formal organisation of work on a weekly and monthly basis is more structured. Not all encounters are left to serendipity.

The analysis of movement and activity through time not only reveals that total movement increased after the deployment, but also that the distribution per time of day changed. Before the deployment, circulation peaked in the morning, decreasing at lunch time and rising again in the afternoon. After the deployment, more movement was registered at the period between the two previous peaks, (11 am and 3 pm). Observations of workers' behaviour in the case-study office reflect this post-deployment behaviour as well (see figures 7.7 – 7.10). It is noticeable that the rhythm of distribution of sitting behaviour throughout the day varied most of all the activities observed. Before the deployment there was a peak before lunch and a decrease during lunch. After the deployment a drop in activity was observed at 10 am, followed by a peak at 11 am, a slight drop at lunch, another peak at 2 pm and a slow drop till the end of the day. Again, this might suggest that people tried to be "more present" after deployment, remaining longer at their desks, perhaps wanting to be more visible and perceived as focused on their work.

To summarise, length of company service affects the volume of visits to other departments. Frequency of meetings reveals more autonomy to hold daily interactions and more structure in terms of weekly and monthly meetings. An analysis of activity through time reveals not only an increase in all activities after the technology deployment, but also a variation of the daily rhythm that might reflect a desire of being perceived as "being there".

7.4 Spatial features and visibility affordances of the office layout

This section combines data from self-reported locations of meetings held and attended in different areas of the office environment, the building and off site with observations of activities mapped in the office plan. The results obtained are further explored using Visibility Graph Analysis. Findings relate to hypotheses 5 and 6 (see Chapter 4, section 4.3.2) that link interaction behaviour to characteristics of its location.

How well different parts of the Nationwide building support meeting activities was discussed with the project champion in detail. The space classification used in the questionnaire - Own desk, Others' desk, Designated meeting rooms, Designated break-out space in office area, Common break-out space (Atrium), Staff restaurant, Off site - hotel etc. (not training course), was an outcome of this discussion. Workers use the atrium break out area on the ground floor for both formal and informal meetings, whereas the office break-out area and staff restaurant are usually only used for informal meetings. Physical indicators of formal/informal behaviour are the use of papers and laptops in meetings. Preliminary observations made on the ground floor further confirm these impressions.

Meetings held by staff

Reportedly, the most popular place to hold meetings is the building's atrium, followed by designated meeting rooms across the building and participants' own desks. Other people's desks, break-out spaces and the staff restaurant follow closely behind (see figures 7.11 and 7.12). The atrium is probably the preferred space to organise meetings may because the tables and furniture are comfortable, there is blanket connectivity across the building with access to the intranet, it is a publicly accessible area and there is sufficient movement and activity to provide both a sense of buzz and enough privacy not to be overheard by neighbouring tables. The second choice, designated rooms, is not surprising, being still the most popular in companies with a formal hierarchical structure. On a daily basis, participants' own desks were the most popular choice for holding meetings, followed by others' desks, while on a weekly basis office break-out spaces were most frequently used, closely followed by designated rooms and atria. This behaviour matches previous research on office space utilisation and can be considered standard use of an office building facilities. Regarding monthly behaviour, it is noticeable the increase in the use of off-site facilities, such as hotels, to hold meetings.

Meetings attended by staff

For attended meetings, designated rooms are by far the most popular locations, followed by the building's atria and the break-out spaces in the office. This might indicate that prearranged meetings, when others require our presence, tend to be of a more formal nature and held in more formal environments. Frequency of attendance was similar to that for held meetings; on a daily basis, the most frequently used space was participants own desks. On a weekly basis office break-out spaces were most popular, followed by the atria and designated rooms. Workers attended meetings at offsite facilities monthly. Aggregating the results per location, it is evident that the majority of the meetings are conducted in the office, whether it is at one's own or at another's desk, a designated meeting room or the group break-out space. A significant 31%of meetings happen in the building (atria, restaurant facilities), and only a small percentage of people's meetings take place off site. See figure 7.13. The frequency of meetings by location – office, building and off site – shows the pattern repeating and a clearer picture emerging. Daily and weekly, the most used location to both hold and attend meetings is the office; at a monthly scale off site meetings increase and people report an increase in meetings held in the building, outside the office. See figure 7.14 for details. The building, as a whole, seems to support formal and informal interactions very well. The differentiation of spaces provided and the legitimacy that the organisation gives to these semi-formal and formal meetings make the spaces work well. This pattern repeats in the office environment. Workers seem to feel comfortable enough to both hold and attend meetings in the flexible areas provided, but one's own desk is still the preferred stop for having a work conversation independently of its motivation. The space use observations show a pattern that enhances and complements the above picture. Activities concentrate overwhelmingly at desks; small and big meeting rooms also show high occupancy levels. The less occupied space is at the bottom right corner of the floor plan, where the senior managers have their desks. Figures 7.17, 7.18 and 7.19, 7.20 show the location of all activities aggregated (before and after the deployment).

Other types of activity

Sitting is concentrated along the periphery of the office but not isolated from the main movement paths. High occupation of the flexible quiet meeting rooms and of the managers cells was observed. The main location for sitting activity is the desk.

Standing activity is centred on the utilities area. There were also some people standing by desks, in the flexible areas and at the entrance corridor, which suggests behaviours such as recruiting (Blackhouse and Drew, 1992). It is noticeable that there are quite a few people walking around the office and talking to others while on the move. This happens mainly with people sitting close to the main circulation areas.

There were two types of talking activities registered: two or more people talking and people talking on the phone. This last activity was concentrated at the entrance of the office (top right corner of the plan), and at the far end of the office (middle left and middle bottom of the plan), possibly because these two areas have call centres. Group talking was mainly seen in the meeting rooms and the flexible quiet meeting areas, as well as in the senior management cells. In the main open plan office space there was a fair amount of talking in groups of sitting and standing people.

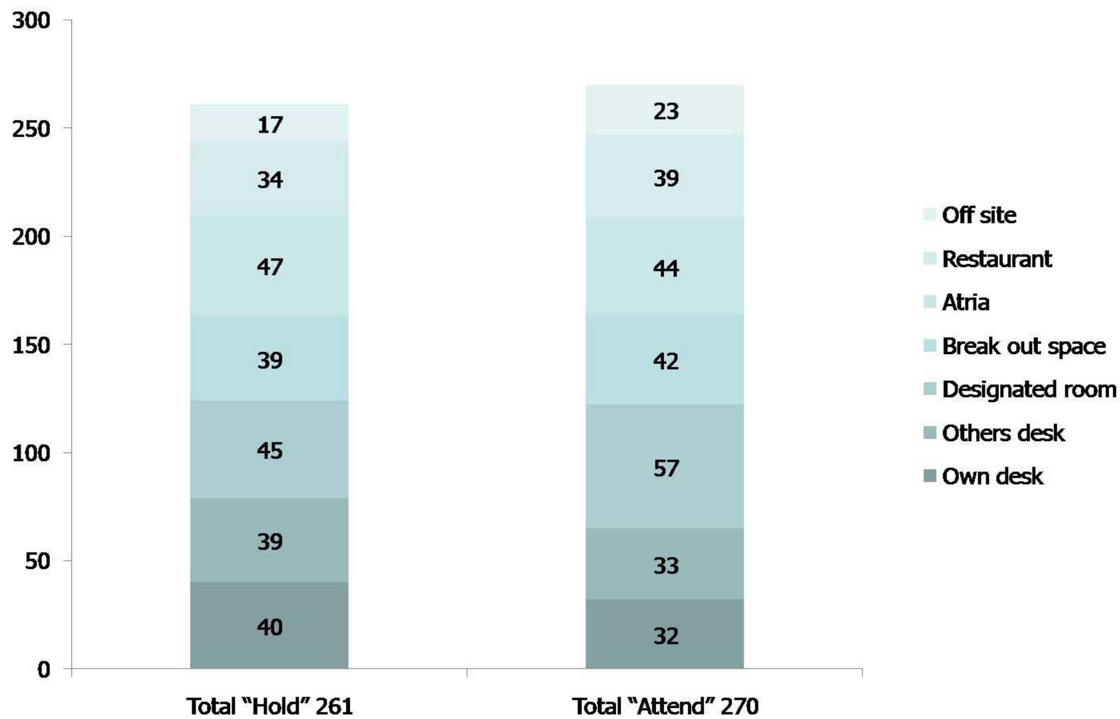


Figure 7.11 Total number of "Held" and "Attend" meetings per area

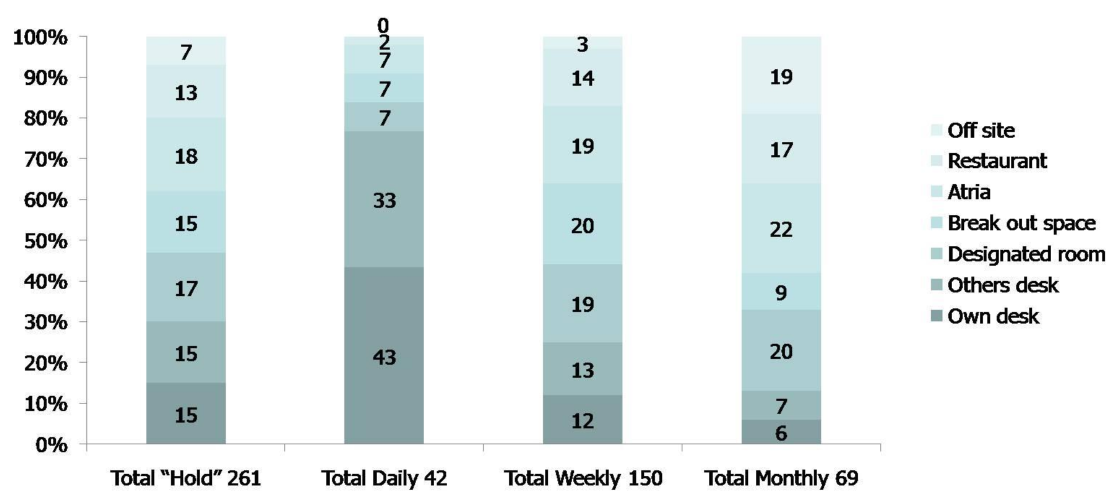


Figure 7.12 Frequency of "Hold" meetings per area

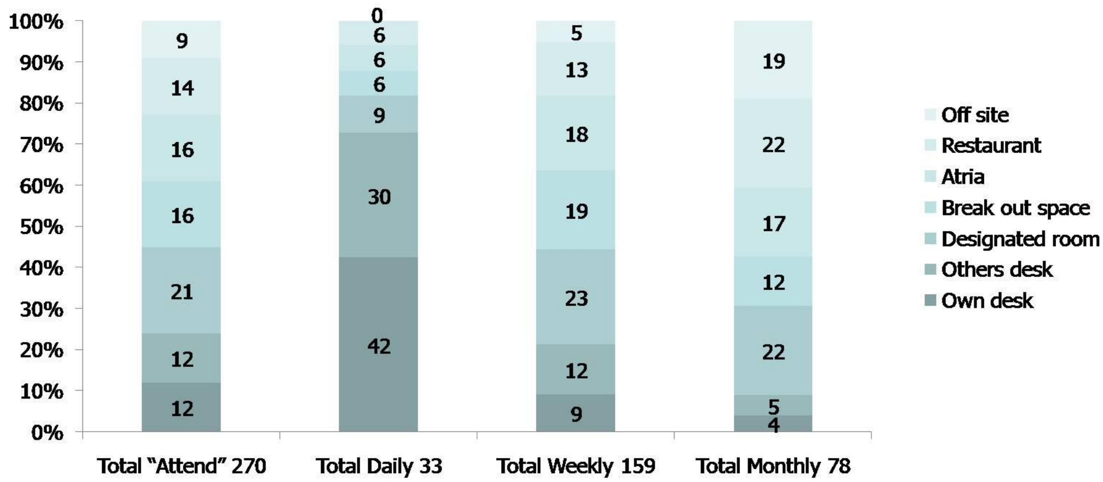


Figure 7.13 Frequency of "Attend" meetings per area

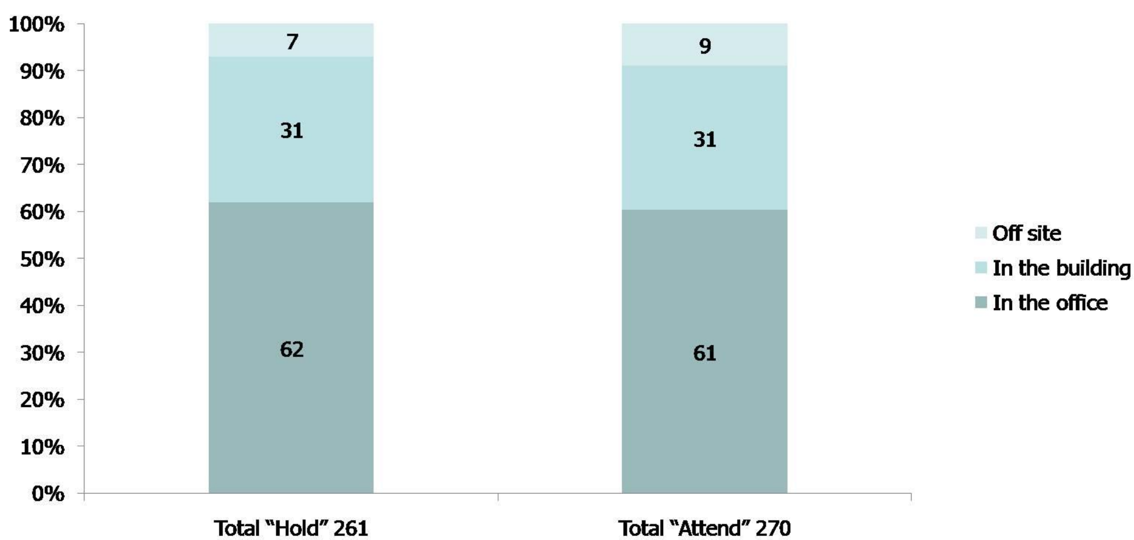


Figure 7.14 Percentage of meetings "Hold" and "Attend" per location.

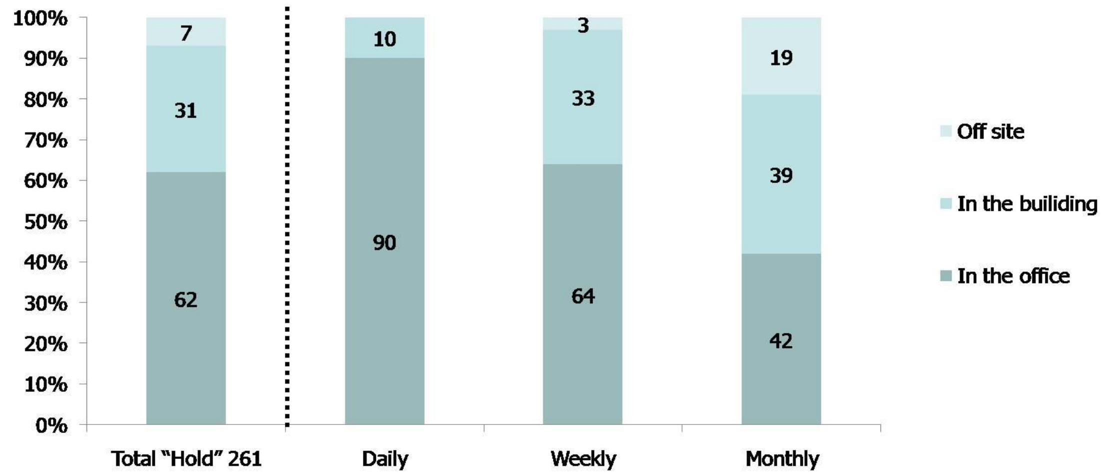


Figure 7.15 Frequency of "Hold" meetings per location.

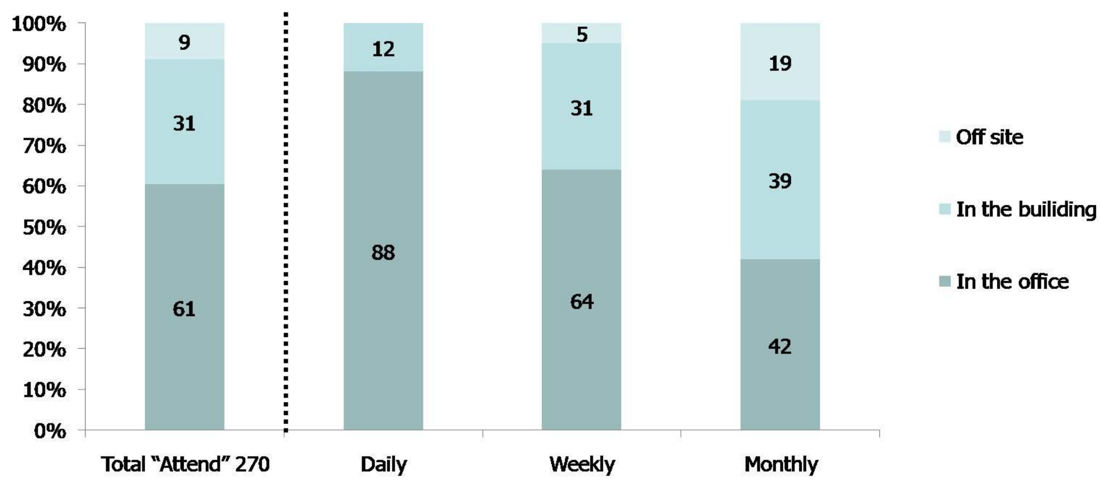


Figure 7.16 Frequency of "Attend" meetings per location.

There was no record of the amount of time spent talking in each location, but the participant observation revealed that conversations at desks were quick and problem solving oriented – workers came to other workers to solve a specific problem with their current tasks. Conversations held in the quiet areas and the senior management areas usually took longer and had more people involved. This has been noted in previous research (Becker et al., 2003; Fayard and Weeks, 2007) and it is an issue that should be included in further studies on physical interaction behaviour in the workplace, as discussed in Chapter 9 and suggested in Chapter 10.

Adding types of work area to the observation data enables further analysis to be made. The floor plan has been divided into six areas: drop in work area, break - out work area, utilities area, meeting rooms, flexible quiet working areas and static fixed positions (see figure 7.21). An analysis of activities by area shows very similar results to those shown by the survey. All recorded activities happen in the area delimiting static fixed positions, that is, the desk area and the space surrounding the desks.

There was an increase in all activities after the deployment, but a decrease in activity in the static fixed positions area. The most noticeable was the increase of activity in the drop-in work area. Incidentally, this area falls inside the location technology deployment perimeter, and those working flexibly might have felt they needed to be “more present” than usual during this period. The use of meeting rooms increased noticeably after the deployment. An analysis per area shows that people talked more at their desks, but also in the drop, the flexible and the quiet working areas, which double as small meeting rooms. This might suggest that informal collaboration is a sign of effectiveness in this particular organisation. It is also a behaviour that is more noticeable, others see and feel your presence more (see figure 7.22).

Observed informal meeting behaviour suggests that most encounters were informal gatherings composed of 2 or 3 people. The locations where they took place were mostly at desks, which agrees with the results of the survey where reported average daily meeting behaviour happens at one’s desk or another’s desk. In the break-out area, and the small meeting rooms, informal work related conversations were also observed. No “formal meetings” observations were conducted although these can be deduced by the number of people using the meeting rooms. The big meeting rooms need to be booked and were quite often but not constantly occupied occupied, by an average of 10 to 15 people. Sometimes, when free, people spontaneously used them for a private phone call or a quick meeting. Other departments can also book and use these spaces.

The layout of the office clearly affects movement patterns. Circulation in the office is concentrated along the main avenue, which is marked by a red carpet guiding detail, see Figure 7.23. The flow of people chooses not to penetrate the group of cells in the middle of the plan formed by the senior management offices, avoiding it and drawing a big elongated circle. By removing the floor plan an illustration of the effects the design of the layout on movement are evident. The managers' offices stop traffic effectively, creating an area that is avoided by natural movement. The rest of the layout, designed with an open plan philosophy, enables permeability and a good flow of circulation in the rest of the office (Becker and Sims, 2001). See figures 7.24 and 7.25. But as has been pointed out before, it seems to be visible co - presence and not movement that is an important predictor of face-to-face interaction and it has been proven that movement has little effects on the relationship between visible co - presence and face-to-face interaction (Rashid et al., 2006). Space syntax research maintains that coawareness and copresence, as a function of visibility, are the base on which particular patterns of encounter and interaction may develop. Visible coawareness and copresence have been found to be the base in which particular patterns of encounter and interaction may develop in the workplace (Rashid et al., 2005; Rashid et al., 2006). These studies suggest that visible copresence outweighs movement and that an office with more visible copresence "may result in more face-to-face interaction regardless of movement" (Ibid.: 842).

Visibility, what one can see, provided by means of physical boundaries or the lack of them, affects how offices work spatially. In buildings, visual fields can provide individuals with information on what to do next, to decide where to go, who to talk to or where to retreat. The role of visual fields is also directly related to the control of information provided to workers. The control of visibility serves the need for privacy to regulate interpersonal interactions. Two specific measures have been related to interaction: visibility integration, visual control and visual controllability (Allalouch and Aspinall, 2007).

A visibility graph is formed by taking a selection of points across a space and forming graph edges between those points if they are mutually visible. Once constructed, it is possible to take measures of various features of the graph. Visibility Integration is a normalised (inverse) measure of the mean shortest path from one point to all other points in the system. High visibility integration means that from a given point an individual or a group can see far and more around them, it has more visual access to other areas. Low visibility integration means the opposite, more segregated spaces and less visual access to other people (Turner, 2001).

Visual control, as defined in The Social Logic of Space (Hillier and Hanson, 1984) measures the degree to which a space controls access to its immediate neighbors, taking into account the number of alternative connections that each of these neighbors has (Klarqvist, 1993). High values of visual control would show controlling spaces, and visual dominant areas (Turner, 2004).

Visual controllability is a measure defined by Turner as the ratio of the number of vertices directly connected to the current point, to the total number of vertices either directly connected to the current point or visible from any of the vertices connected to the current points. The result of this measure is to highlight locations that are visually strategic from the point of view that they are difficult to control. High values of visual controllability would show controllable spaces - areas "that might be easily visually dominated" (Ibid.: 16).

Visibility Graph Analysis is used in this section with two purposes: to talk about the office features and their effects on visibility, and to discuss the observations and questionnaire findings in relation to specific layout properties – visibility integration, control and controllability. A VGA analysis of the office layout excluding moveable furniture and glass partitions shows that the areas with higher integration are the open plan and the drop-in areas. These spaces show higher visual access than the rest of the office. Segregated areas, where there is less visual access to other areas are the flexible quiet areas and the senior management area. The area of higher control is the area that connects the utilities area, the beginning of the senior management office cells, the break out area and the main entrance to the office. This hub is visually the most strategic point within this space, for it controls visibility access to the rest of the office. Less controlling spaces match the segregated spaces found with the previous analysis. The areas with higher visual controllability are the open plan and drop in area and part of the call centre area. These are spaces where visual control by occupants is easy. Areas with low values of visual controllability match those with less integration and less control. This might mean that in this office the segregated areas, with less visual access to the rest of the office, are also spaces where there is little visibility control over others and that are difficult to control visually by their occupants.

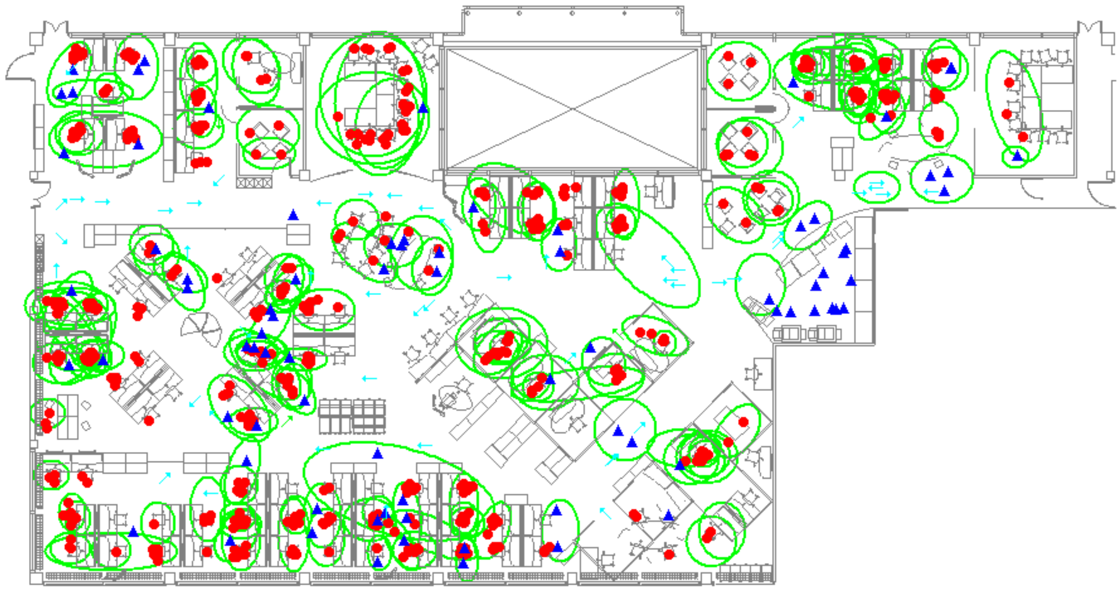


Figure 7.17 Aggregated activities in the office, before the deployment.

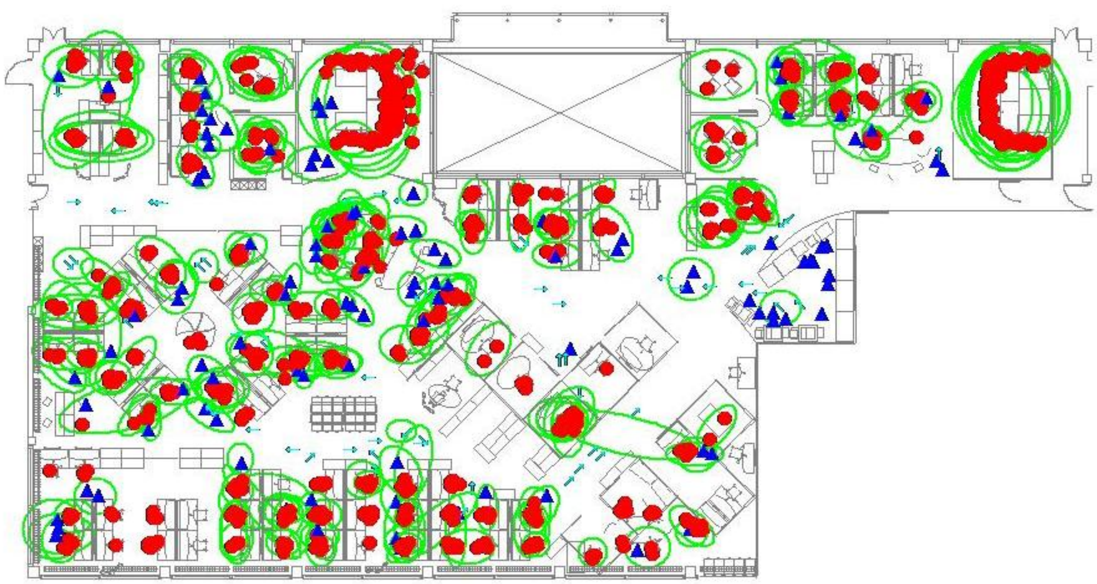


Figure 7.18 Aggregated activities in the office, after the deployment

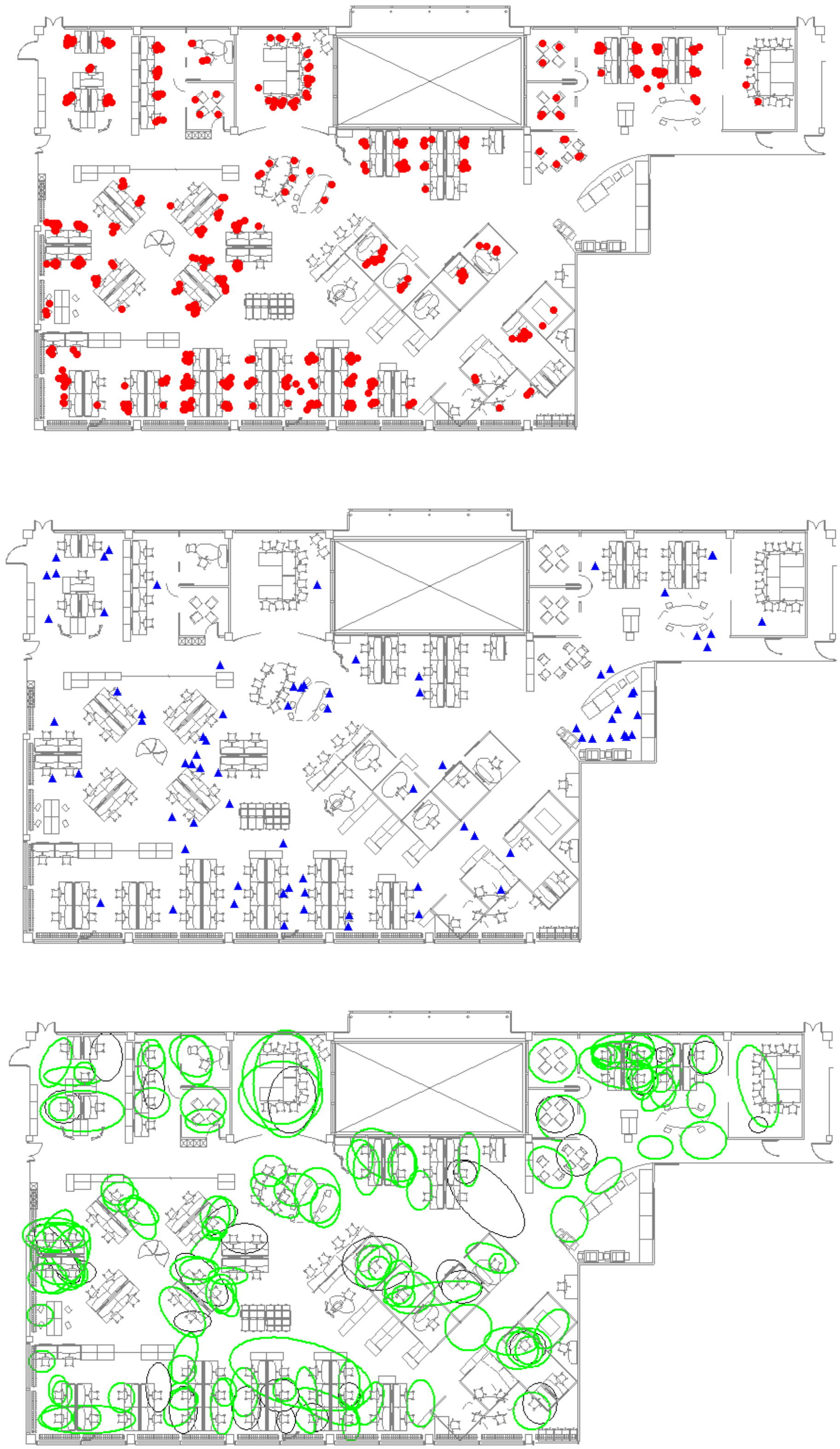


Figure 7.19 Location of Aggregated activities, sitting, standing and talking, in the office, before the deployment.

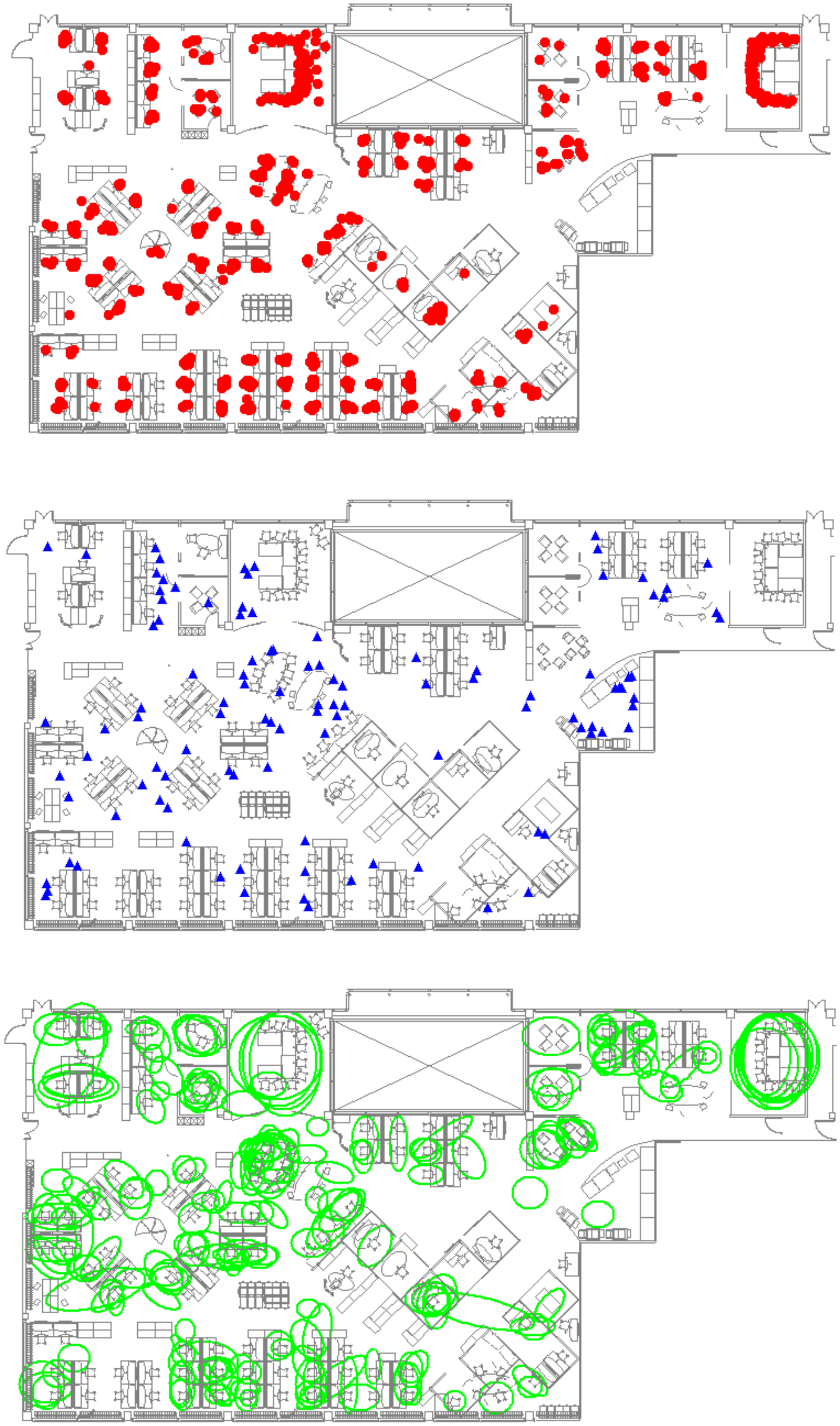
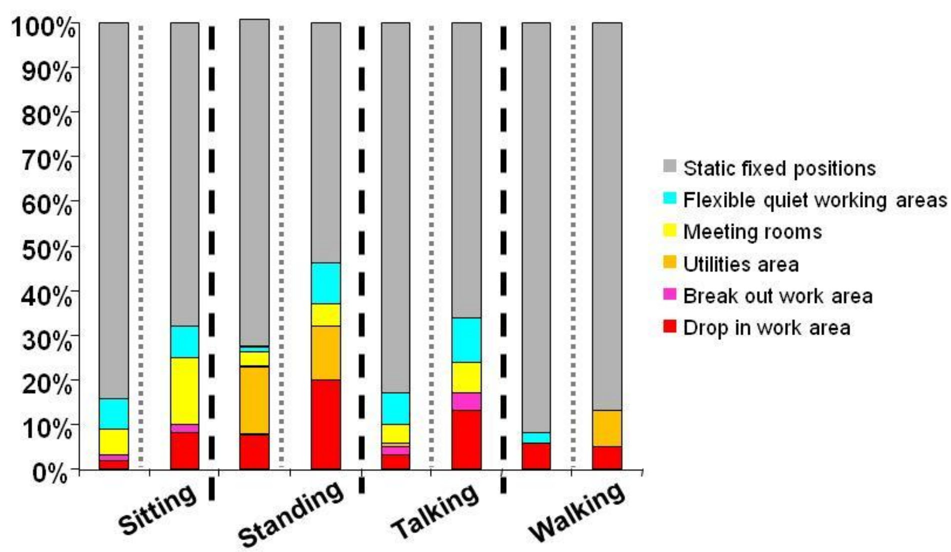


Figure 7.20 Location of Aggregated activities, sitting, standing and talking, in the office, after the deployment.

Figure 7.21 Types of work area in the case study office.



	BEFORE				AFTER			
%	**Sitting**	**Standing**	**Talking**	**Walking**	**Sitting**	**Standing**	**Talking**	**Walking**
Drop in work area	2	8	3	6	8	20	13	5
Break out work area	1	0	2	0	2	0	4	0
Utilities area	0	15	1	0	0	12	0	8
Meeting rooms	6	3	4	0	15	5	7	0
Flexible quiet working areas	7	1	7	2	7	9	10	0
Static fixed positions	84	74	83	92	68	54	66	87
Total	100	100	100	100	100	100	100	100

Figure 7.22 Distribution of activity, Before and After deployment, per area in the office

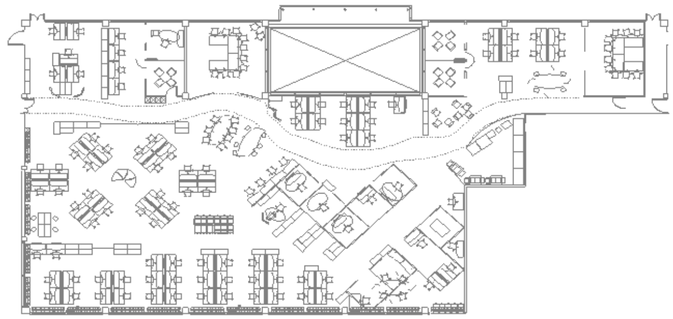


Figure 7.23 Red carpet guiding detail

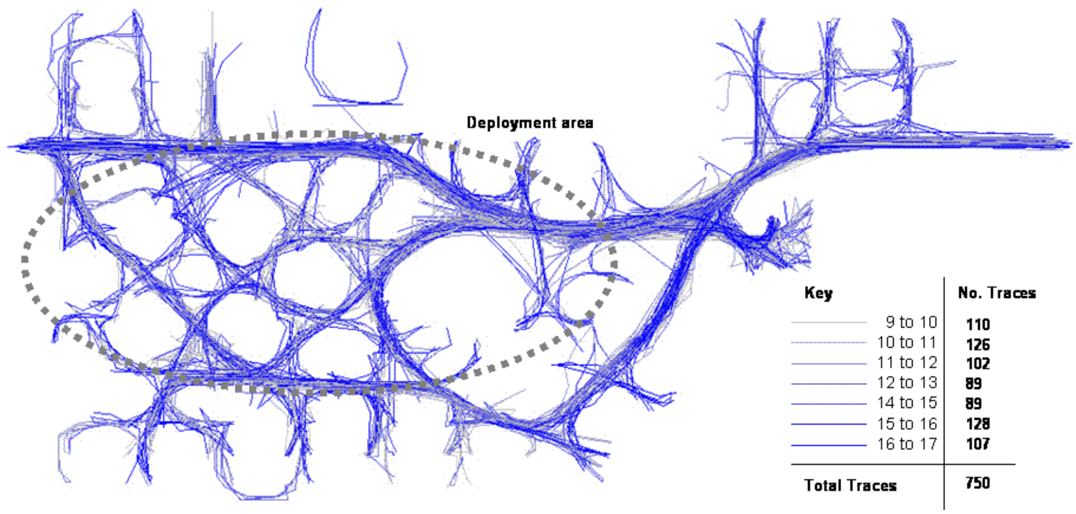


Figure 7.24 Before all movement aggregated

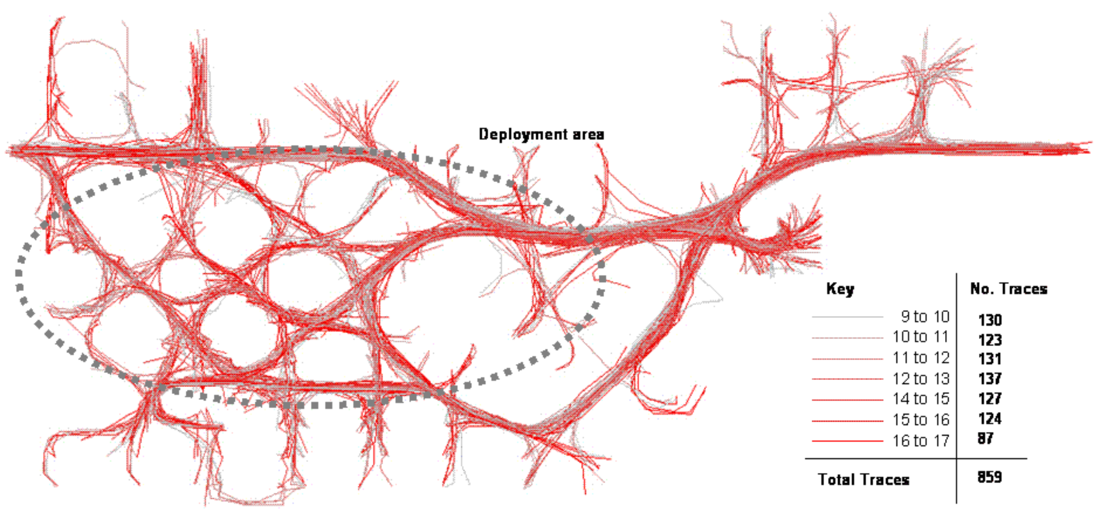


Figure 7.25 After all movement aggregated

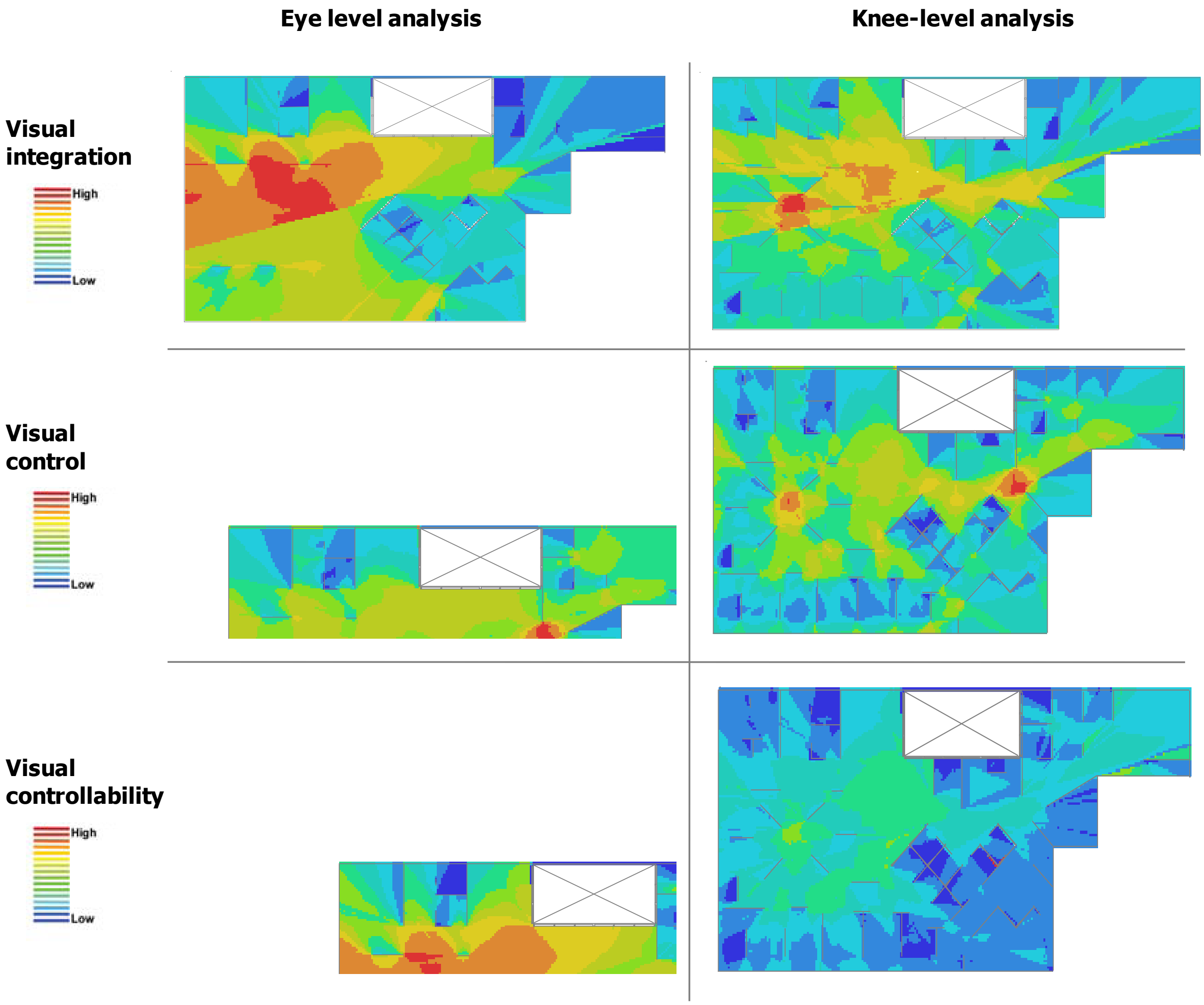


Figure 7.26 Eye level and knee level analyses of Visibility Integration (HH), Control and Controllability

Analyses at knee-level, including furniture, show similar results. See figure 7.26.

Comparing the visibility analyses results to the findings reported before, the patterns of movement and activities observed and reported can be linked to specific properties of the spatial layout. The spatial analysis shows that the above mentioned characteristics of the different spaces support different types of interaction patterns, both observed and reported. It seems that the organisation designed different spaces to encourage different work behaviors, and the results of the visibility analysis compared with the observations and reported behavior confirms this. The layout of the office supports the behaviors that the management wanted to promote.

The open plan area - the most integrated space, supports informal, brief conversations between colleagues, whereas the drop in area registers continuous occupancy and casual conversations and impromptu meetings. Segregated areas, meeting rooms, flexible quiet areas and the senior management cells support different types of interaction, involving more people and taking more time. Again, this aspect is a result of the participant observation conducted in the office environment and not from the observation data.

7.5 Summary of Findings

The results of the survey and of the space use observations give evidence against which the automated method analysis can be contrasted. The analysis provides clues to interaction behaviour, its complexity, how it is bound to the office layout, to the deployment of the technology and to the organisational context. Adding the knowledge acquired during the case study to the findings above, it is possible to draw a picture of the formal and informal meeting arrangements in which the population of the A2 room, participate, and of the interaction patterns generated through movement and work related activities in space through time. Unsurprisingly, findings obtained through manual and other methods cannot drill down to the specific information needed to support or reject the hypotheses set out in chapter 4 to test the potential of the automated method, but they do provide additional information that characterises work from a different perspective.

To increase the detail of those behaviours, additional questions and observations would have been needed. For example, specific questions on the duration of different types of meetings linked to those questions asking where and how often meetings were held would have provided a good overview on meeting behaviour, although this would have been subject to the individual’s perception which is subjective by nature. Also, specific shadowing techniques could have been applied to complement the perceived meeting behaviour. A highly well trained observer could have shadowed different types of meetings in different areas of the office and building, taken notes and questioned the participants afterwards. It is important to point out that this part of the study does not include observations or questions about solitary work. And it is a fact that it was only when a close examination of the location tracking dataset combined with extensive reading on pre-conditions for interaction took place that the inclusion of a measurement of the counterpart of physical interaction became more and more relevant. It is also worth mentioning that no standard workplace survey includes questions about solo time and solitary work, apart from those related to distractions provoked by environmental conditions and open plan designs. When this investigation was designed, the focus was on understanding interaction and work activities and did not include solitary work as one of them. All these are ideas that can be applied in future office studies focused in interaction in the workplace.

There is something that this analysis does that the automated method cannot do, and that is the measurement of behaviour before and after the technology deployment. It is worth noticing that the "Before" and "After" comparison outcomes – reporting an increase in activities and behaviour after deployment – may not be due exclusively to the technology deployment. The results report behaviour at one point in time, and the deployment is one variable of many that might have caused an effect on the activities observed.

An office environment is a multilayered reality, which is also an environment of multiple boundaries physical, organisational and technological. This part of the investigation shows the resulting overlapping layers of spaces, organisational rules and technology and their combined effects on worker's behaviour. There is the office space – the A2 room – within which is located the more circumscribed deployment area. There are movement routes and there are spaces that are visited daily by the workers that are located outside the office but are in the same building (atria, restaurant). There are interaction dynamics that are enabled by the organisational structure and culture and by the building and its layout. It is very difficult to understand this complex context through one approach and using one set of tools. The next chapter shows how this picture can be segmented and complemented using precise location and time data.

Key Points

- Patterns of interaction behaviour and work related activities seem to be influenced by the organisational culture. It is legitimate to interact with others and the building is there to support this policy.
- Nevertheless, a frequency analysis reveals that while workers seem to have more autonomy to organise their daily encounters, when it comes to weekly and monthly meetings there seems to be more structured routines, possibly encouraged by the organisation.
- There is a clear increase in all work activities after the technology deployment which might signal a collective reaction to mitigate a potential surveillance threat.
- The most popular places in the office for informal interactions are desks and the drop in area.
- Visibility analysis of the layout reveals a good match between visual affordances of the office and interaction patterns.

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[i] An exploratory paper presenting some initial thoughts related to this and the next chapter was submitted in a sociology conference organised by the British Sociological Association in Aberdeen in 2007 (Lopez de Vallejo, 2007).

Chapter Eight:
Automated observational measurement of interpersonal spatio – temporal dynamics in the workplace

Abstract

How well can interaction and solo dynamics be portrayed using accurate location and time data? The fairly static, discrete and short-term picture of behaviour portrayed in the previous chapter supplies the backdrop against which, together with the hypotheses posed in Chapter 4, to test the potential of the automated method. In this section of the thesis mechanical systematic observations results, whose logic and structure are described in detail in that same chapter are presented. MATLAB results are analysed using descriptive statistics and visualised using tables, graphs and plans. Output information characterising spatially and temporally interpersonal dynamics is then faced up to the hypothesis. Results are further investigated using visibility analysis measures. The end result lays the groundwork for further comparison of both manual and automated techniques in the subsequent chapter.

8.1 Introduction

The previous chapter starts by highlighting evidence provided in Chapters 2 and 3 regarding the lack of empirical verification results of many studies that touch on workplace design and interaction behaviour through time suffer from. It is still today, despite of partially successful attempts from different disciplines to solve it, tremendously difficult to portray in detail the pervasive nature of interaction dynamics through time in the workplace In Chapter 4 it was pointed at that in this thesis systematic observation is the research strategy chosen to quantify behavior that occurs in a naturalistic context – in this case the Nationwide A2 room office environment. In Chapter 7 different forms of behavior in offices – behavioral codes such as sitting, standing, walking and talking, are used to observe behavior in the office and to record it. By contrast, in this chapter, new behavioral codes have been developed aiming to measure in detail interaction behavior through time.

The observer in the new automated method is a location tracking system that records precise location through time, down to the second. This automated observer gathers a dataset that is extremely large, very precise and fairly simple. The output is a set of excel spreadsheets with date, tag name, time (in format mm:ss:ms), Cartesian coordinates associated to each tag, distance travelled between readings and number of samples taken per reading[1] (see figure 4.4 in Chapter 4). Location tracking technologies can provide very precise position and time information which are the basis for a highly granular exploration of interaction patterns. What these systems do not provide are the tools to transform raw location data into meaningful and manageable interaction information. The key challenge this thesis faces is the post processing of that raw dataset. To do that it is necessary to develop new codes[2].

Codes are measuring instruments that "specify which behaviour is to be selected from the passing stream and recorded for subsequent study" (Bakeman and Gottman, 1986:5). The behavioural codes used in this chapter are a means to extract specific spatial and temporal information of interaction behaviour in the context of the office. Chapter 3 has reviewed what is important conceptually and the literature has been screened to identify a number of variables that can be used to measure some of those aspects of interaction behaviour. The reliability of the measuring instrument – the technology, has been discussed in Chapter 4. The new codes have been developed take the advantage provided by the potential of the technology to record precise position every second. The codes measure behavioural states that are mutually exclusive (Interaction or Solo), and exhaustive - individuals are either involved in the specific event or not (on – off state). Where a human observer would be asked to identify events of interaction and events of solitary time, the unprocessed dataset has to be interrogated mathematically to identify and record those events. The triggers are the trespassing, or not trespassing, of a circular boundary of 0.75 m that has been drawn around each tag. Interaction is registered when two or more of those circular boundaries overlap for more than 15 seconds, and solo events are recorded when that boundary is not trespassed by another boundary at all. A metaphor can help to illustrate this process. The location tracking system is a highly capable observer that sees everything and is able to record it in a very precise way, recording specific location down to the second. MATLAB, his colleague observer, is a bit pickier, and his job a bit more specialised. He has to look into the massive data stream that his highly capable but undiscriminating colleague has gathered and identify when some predefined mathematical conditions, the behavioural codes, take place, and record them. The outcome is still large, but at this point a third observer – the researcher, free from the straitjacket of an unprocessed dataset, can start not just to analyse it, but also interpret it and therefore render it meaningful.

The analysis is concerned with:

- frequency behaviours – momentary events and their amount (H1)
- and number of people involved (H3),
- behavioural states – duration behaviours or the proportion of time devoted to a particular kind of event (H2),
- spatial behaviors – where events take place, precise location of behaviour (H4, H5).

Before starting to describe the analysis and findings, a description of the output dataset after its manipulation in MATLAB is presented. This is made in order to introduce the difficulty of dealing with a vast amount of information. After the analysis, the final section summarises the findings relating them to the hypotheses and sets the ground for the discussion and comparison of methods in Chapter 9.

8.2 Description of the dataset

The UWB technology pilot provided 23 days of raw data, four full weeks and 3 days, out of the 28 days the system was deployed. See figure 8.1. During that period of time, no particular event took place in the office, apart from the deployment itself. The number of unique tags handed out to workers was 51. The manipulation made in MATLAB of this raw dataset – as described in Chapter 4 – produced three sets of multiple spreadsheets, each set covering all days of the deployment. One of the sets produced data on solo events with the following fields: tag number, x position, y position, number of seconds. Each entry is a unique event. The other two dealt with different aspects of interaction events, including the number of people involved. See annex J for details.

To understand the structure, complexity and variability of the output dataset a description is presented based on three criteria: changes in the volume of tags actively emitting signals throughout the whole period of 23 days; amount of time the system was active each day and throughout the deployment; volume of solo and interaction events recorded during this time.

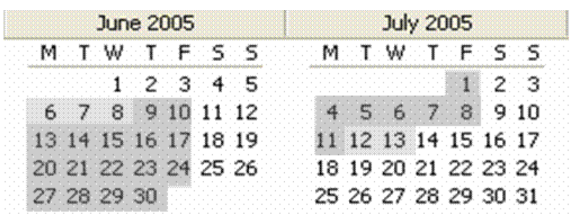


Figure 8.1 Deployment time scale and days with data in dark grey.

There are variations in the number of unique tags active throughout the period. See figure 8.2 for details. Days 1 and 12 show particularly low numbers of active tags. The third week of the deployment – days 8 to 12 in the graph, sees a progressive decrease in volume of tags. This picks up the following working day that sees the second highest amount of tags of the whole period. Numbers then stay elevated until the last day of the deployment. These differences can be explained as a result of technical and social issues mentioned in Chapters 4 and 6. Technical problems during that period, participants interest in the pilot wearing out and individual's behavior towards the deployment combined, account for the decrease in readings. Apparently insignificant issues such as forgetting to check the batteries (flat battery equals no signal), or forgetting to wear the tag and leaving it on the desk (stationary tags disappear from the system , "go to sleep"), affect the volume of readings. These factors combined are the reason why there is not one day that has 51 tags actively emitting information.

Once the technical problems were identified and solved, as has been explained in Chapter 6, the Head of Research at Nationwide, out of concern for the perceived loss of interest and the observed behavior towards wearing the tag, made a strong effort of communication to encourage participants to wear the tag at all times in order to palliate the observed behavior and get more data for his own technology project. Two specific experiments were set up in order to get more people wearing tags: the "Twix Communication Note", issued on Tuesday 28th June, and "Candy in the flexible area" conducted on Wednesday 6th July. In the first case, a printed communication was left in each participant's desk with the title "**T**eams **W**orking **I**n e**X**cellence" enthusing them to help the company get good data out of the technology deployment. A Twix bar was placed on top of each note. See annex A for details. "Candy in the flexible area" was a simple experiment to get people moving around the office and record the movement through the system's visual display and a software called SnagIt7. As its name suggests, different types of candy were placed on the main table in the flexible area. Tag wearers were asked at different times during the day to get up from their desks, walk to the table, pick up apiece of candy, stay for a couple of minutes eating it and/or talking to someone else who was doing the same, and then walk back to their desks at a normal pace. This event is only recorded in the participant observation diary. No formal communication was issued at the time.

The resolution of the technical problems can be traced through the data. Figure 8.3 shows the proportion of time the system was active throughout the whole period, per day. After a couple of days of full functioning a dramatic drop is recorded on the 17th June – day 7. Problems solved momentarily for two days and again another, less dramatic, fall of activity took place. Once the problems were resolved, the system functioned well for most of the time (24 hour periods). The days that the experiments were conducted on are circled in grey-blue. Figure 8.4 presents the same data analysed in relation to the typical working hours. So the system functions most of the time, but does it during the working hours, which, after all, is the period of real interest for this thesis? Typical working hours for the 51 workers were 8 am to 6 pm, with flexibility in checking in and out. Figure 8.4 highlights with a light grey rectangle the proportion of time the system was active. It turns out that the system covers all of the working hours through the period, 13 days out of 23, so the system is locating the tags and recording position and times all of the working hours of 13 days, and partially the other 10. On those days, the coverage is reasonably wide except for the 13th, 17th and 11th July – days 3,7 and 23 circled in red in the graph. This small piece of analysis allows to drop those days from the study, for the working period covered is very short.

The effects of the technology problems, social issues and of the experiments can be mapped out in an initial analysis of the volume of solo and interaction events. Figure 8.5 shows the total number of solo events greater than 10 seconds in duration, and interaction events that last at least 15 seconds or more recorded by the system. The graph illustrates a clear difference in the volume of data recorded between the first three and the last two weeks of the deployment. After an initial peak, weeks 2 and 3 witness a continuous fall in events recorded. Weeks 4 and 5, by contrast, record an increase in readings with peaks that align with the communication experiments. Technical reasons may account for low number of events on days 3, 7 and 23, but they are not a potential reason for the low readings in week 3 as the system was functioning during those days for most of the working day. Despite this, the number of unique tags active during those days is the lowest of the period. It is possible that participants stopped wearing the tags, which was also a behavior noted during the participant observation.

Despite the variability of the dataset, there were enough tags to be able to describe the participants behavioral patterns, there was sufficient coverage of the office environment through the working days, and although the number of output events are still considerable, they are at this point manageable and suitable for the analysis proposed.

8.3 Physical interaction and solo events: quantity and frequency

This section looks at the amount of interaction and solo events recorded, as well as the portion of time the participants spent together, as a collective, both per day and throughout the period. . All interaction events lasting less than 15 seconds have been discarded for the analysis and only solo events, only solo events that last more than 10 seconds have been included. It was pointed out in Chapter 4 that these values were arbitrary but were led by the scarce findings on interaction and solo behavior in naturalistic environments which, incidentally, this thesis aims to challenge. An analysis of individual tags could have been done, but as was noticed in Chapter 6, the nature of the technology pilot was anonymous, and each person had to leave their tag at the end of the day and take another one in order to preserve anonymity of participants. Also the sheer volume of data and the lack of questions aimed to understand specific individual's patterns of behaviour to trigger that analysis, make that particular piece of examination irrelevant for this thesis.

Figures 8.6 and 8.8 present an analysis of the number of events identified and recorded shows 44% interaction events held versus 56% solo events. 12% more solo events are held throughout the period. An analysis per day of deployment of the proportion of events serves to illustrate the trend and the changes through time, with exceptions on six days. Looking at the amount of time participants spent on those states, the difference is sharper. 69% of the time is spent in solo events whereas 31% of the time is spent in face-to-face interaction. A daily analysis exemplifies the trend that repeats with two exceptions (days 10 and 12) along the period. See figures 8.7 and 8.9. It is noticeable that during the first three days of the deployment there was a much higher proportion of solo events than interaction

Figure 8.2 Volume of unique active tags per day of the deployment with data.

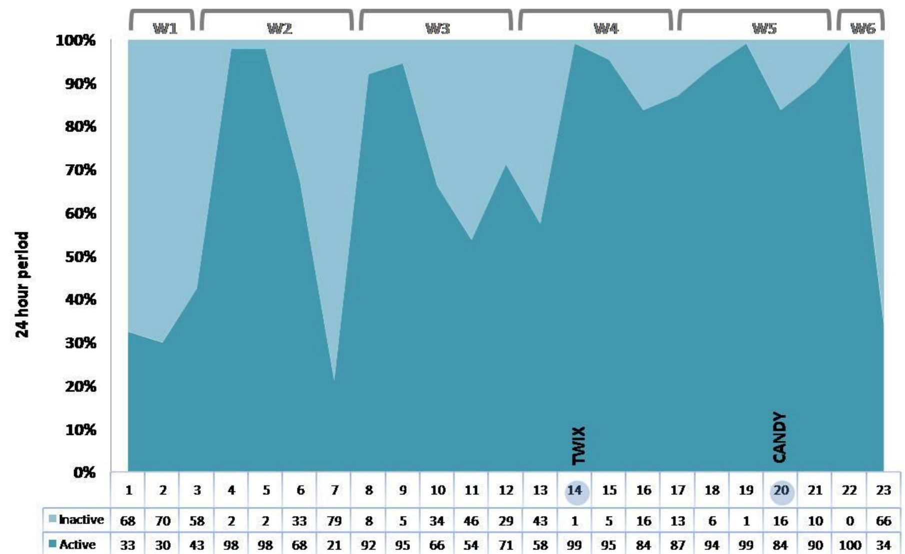
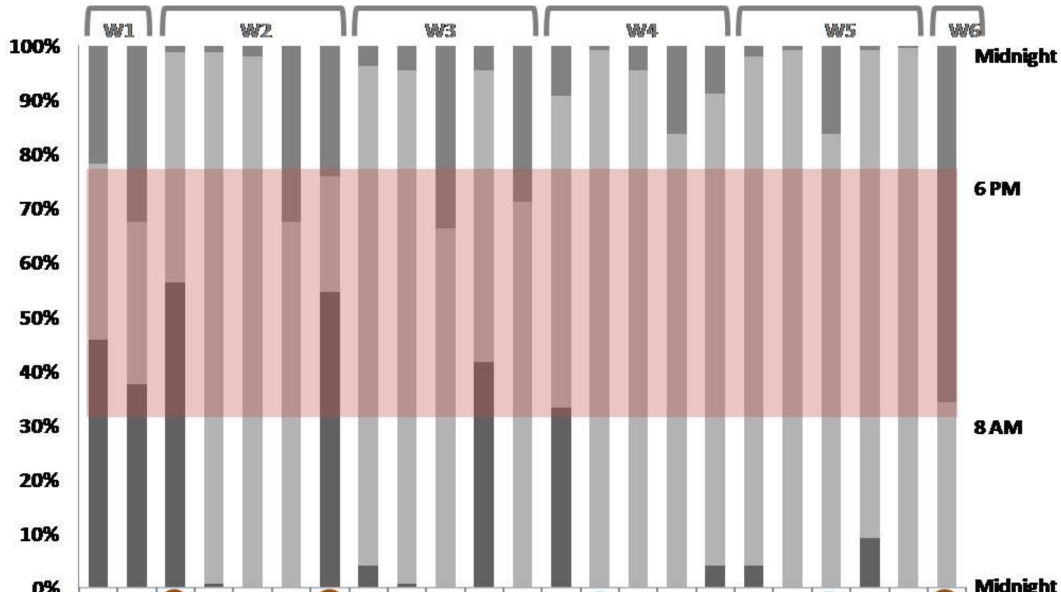
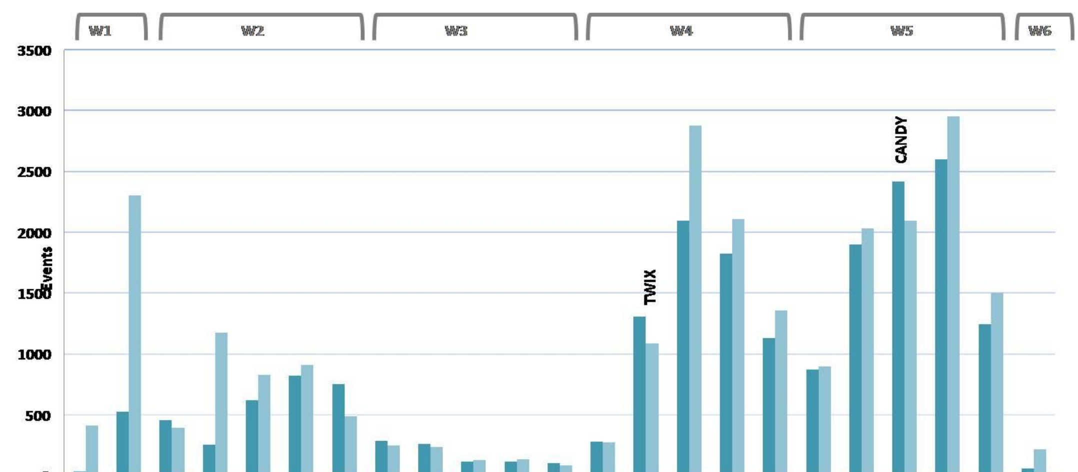


Figure 8.3 Percentage of time the system was active and inactive per day of the deployment with data.



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Inactive PM	22	33	1	1	2	33	24	4	5	34	5	29	9	1	5	16	9	2	1	16	1	0	66
Active	33	30	43	98	98	68	21	92	95	66	54	71	58	99	95	84	87	94	99	84	90	100	34
Inactive AM	46	38	56	1	0	0	55	4	1	0	42	0	33	0	0	0	4	4	0	0	9	0	0

Figure 8.4 Percentage of time the system was active and inactive, related to the typical working hours (shown as the pink bar) per day of the deployment with data.



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Interaction events	36	531	460	257	621	822	753	290	263	121	117	103	285	1311	2100	1828	1134	877	1899	2421	2599	1244	59
Solo events	413	2305	396	1178	829	911	488	253	239	130	136	90	275	1086	2880	2109	1359	898	2032	2099	2954	1505	217

Figure 8.5 Number of Solo and Interaction events recorded per day of the deployment with data.

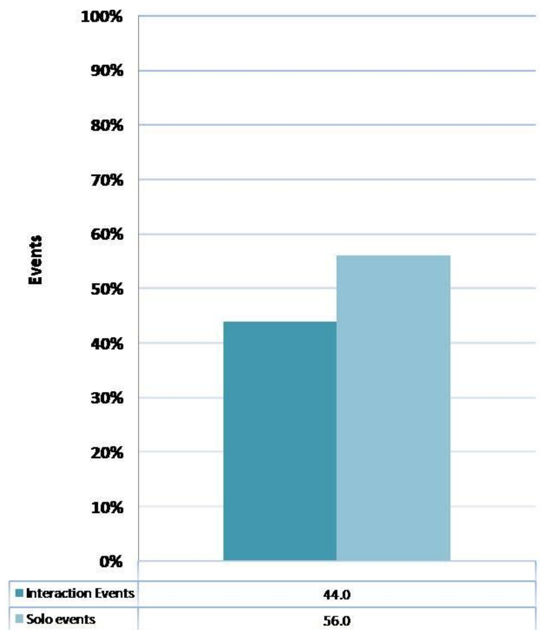


Figure 8.6 Proportion of interaction and solo *events* throughout the period.

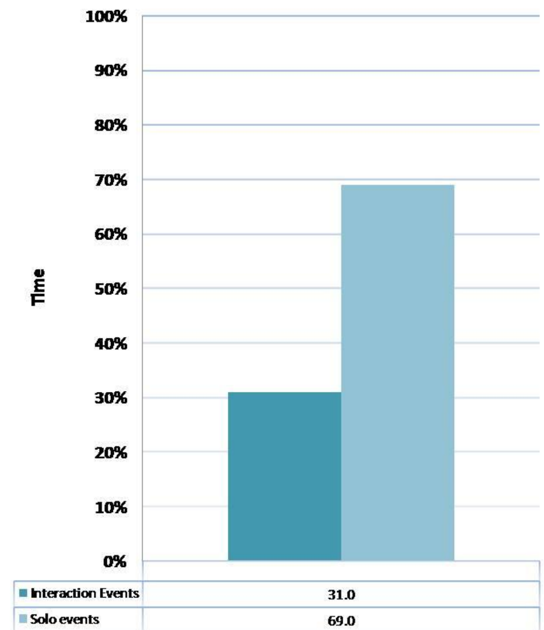


Figure 8.7 Proportion of *time spent* in interaction and solo events throughout the period.

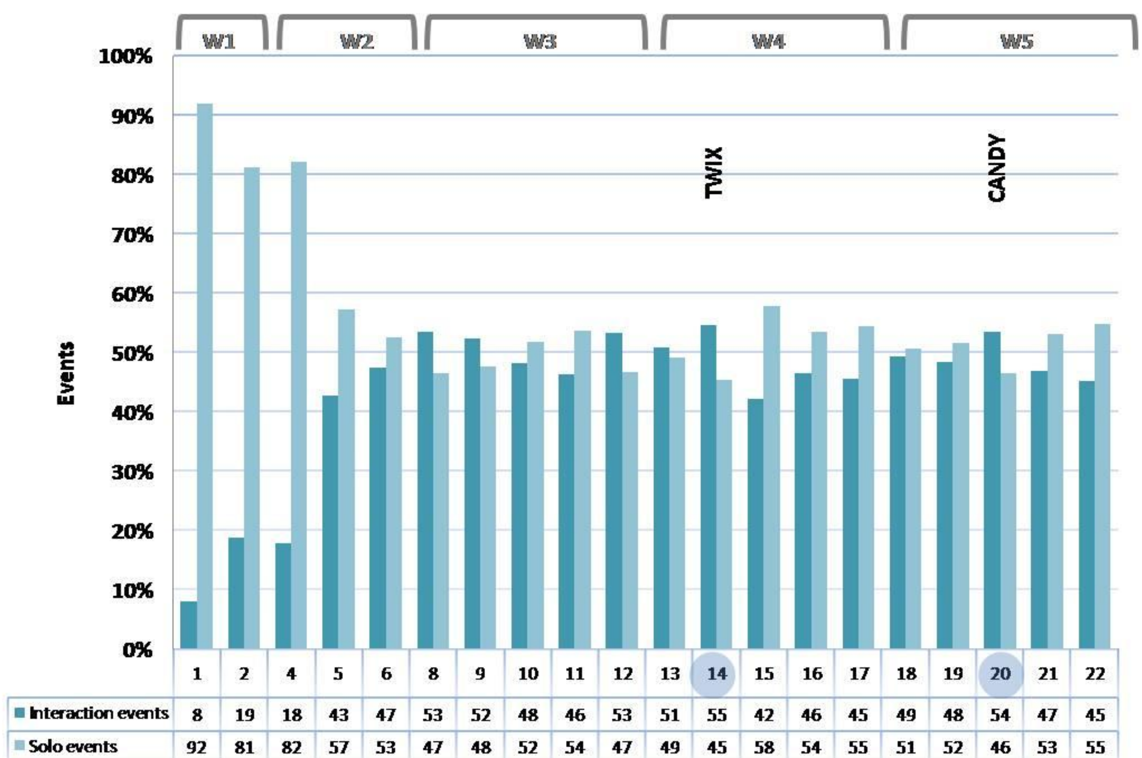
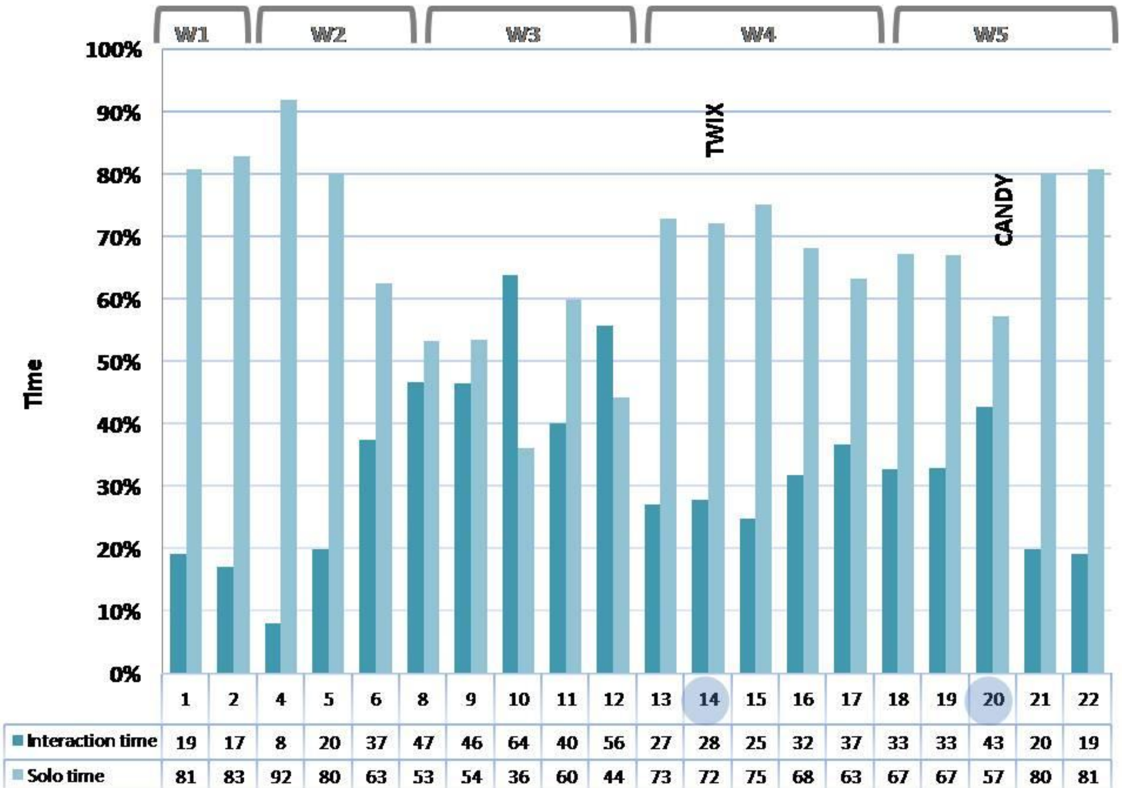


Figure 8.8 Percentage of interaction and solo *events* per day of deployment.



	1	2	4	5	6	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Interaction time	19	17	8	20	37	47	46	64	40	56	27	28	25	32	37	33	33	43	20	19
Solo time	81	83	92	80	63	53	54	36	60	44	73	72	75	68	63	67	67	57	80	81

Figure 8.9 Percentage of *time spent* on interaction and solo events through the period.

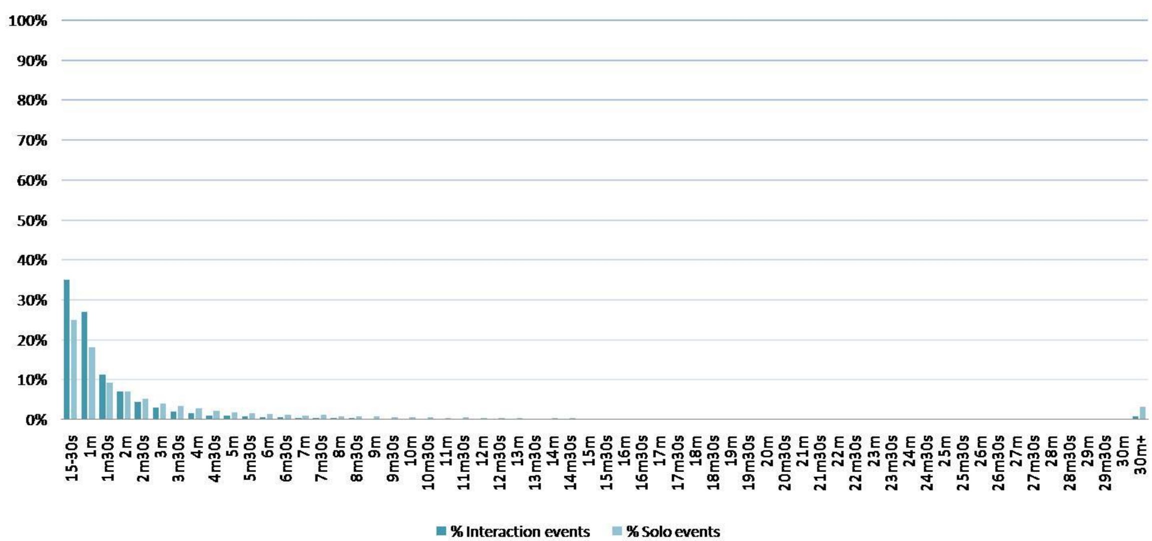


Figure 8.10 Percentage of interaction and solo events by time bands.

events, and that the amount of time participants spent alone was also greater.

This low number of face-to-face interactions and little time spent interacting could have been due to initial fears of being spied on by the technology. In general, participants collectively have slightly more episodes of solo events than face-to-face interactions and spend much more time alone than interacting, supposedly engaged in solo work related activities.

8.4 Temporal structure of interaction and solo events

The time granularity of the system allows further analysis of all interaction and solo events and their duration in seconds. A series of time bands have been created and events sorted accordingly. These bands allow the events and the amount of time spent on them to be categorised in a numerical way. Also, the granularity of the data allows examination of the average duration of solo and interaction events per day of the deployment. The combined results permit an interesting description of the temporal structure of interaction and solo events in this office environment.

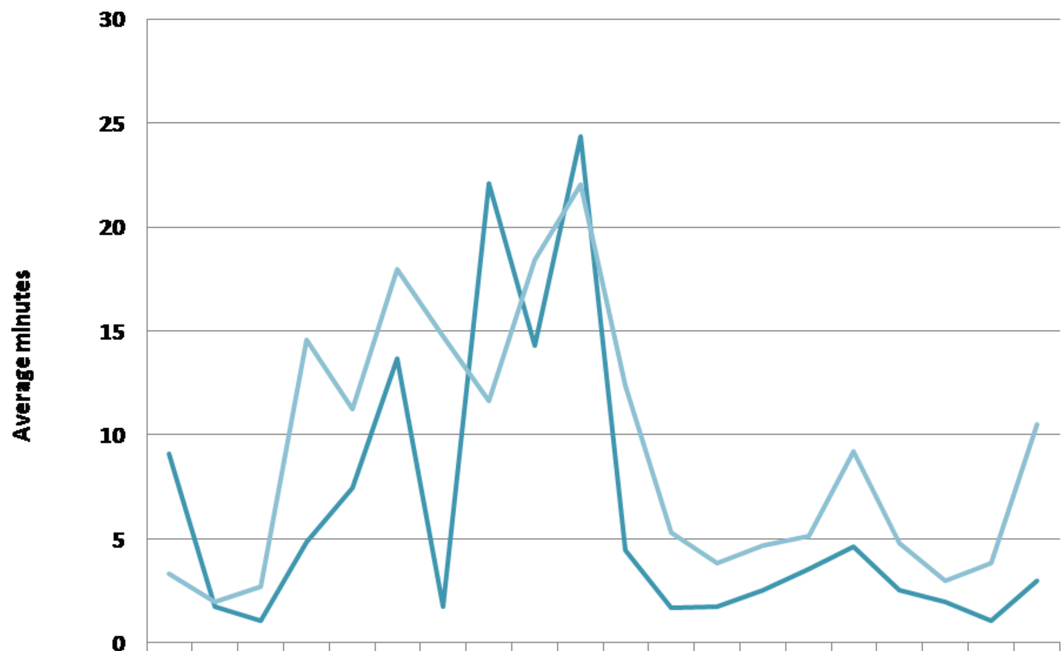
All interaction events have been classified into bands as follows: 15-30 seconds, 1 minute, 1minute 30 seconds, 2 minutes, and every 30 seconds after that up until 30 minutes, finishing with a 30 minutes plus category. Solo events time bands are similar to those for interaction events except that the first band is 10 seconds and the second band is 10-30 seconds. This extensive classification has been enabled by the precise time information obtained by the system and it makes possible to classify and count very short interactions.

The results of the analysis for the whole period show that 80% of face-to-face interaction events concentrate on the briefest time bands, lasting less than 2 minutes. 80% of all solo events last less than five and a half minutes. See Figure 8.10 for details. So whereas most events are brief, face-to-face interaction events tend to be briefer than solo events, 2 minutes versus 5 minutes in duration. These results are corroborated by an analysis of the average duration of interaction and solo events.

The mean duration of solo and interaction events has been calculated by adding every single event recorded, per day of deployment and dividing it by the number of total unique events recorded during the day. This simple arithmetic mean gives an idea of the average duration, or the typical amount of time spend on interaction and solo events.

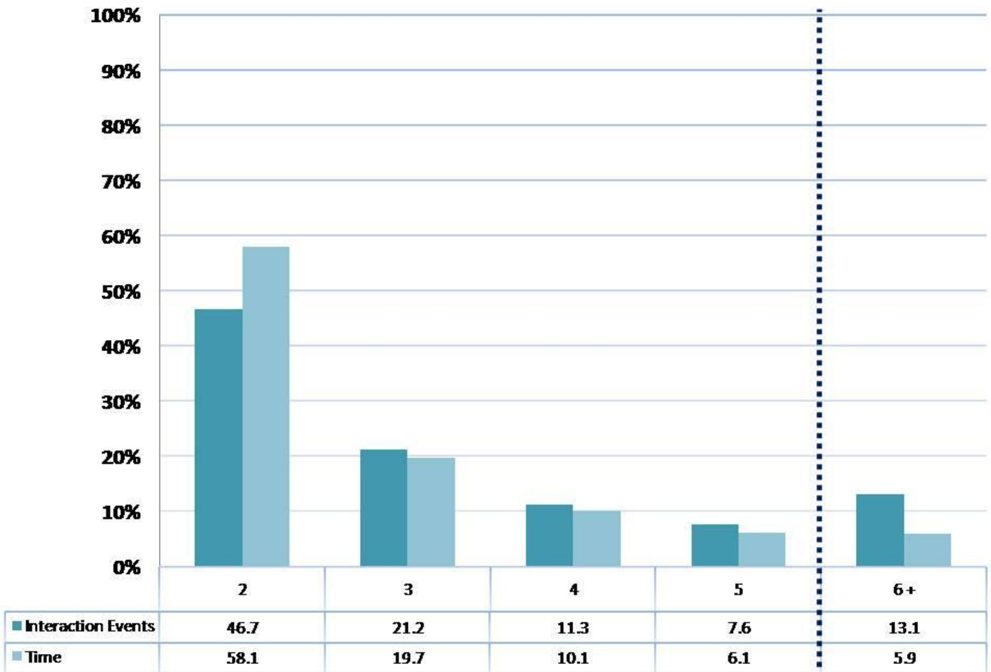
The analysis is also showed per day to illustrate daily variations through the period. In this office environment, face-to-face interaction events last an average of 6 minutes and solo events have a mean duration of 9 minutes throughout the period. In both cases the amount of time spent on average in each event decreases through the five week period. See figure 8.11. If these numbers are compared to those presented in figure 8.5, number of interaction events, it seems that the more interaction events recorded the shorter in average those events are.

This cannot be considered a real result for to be able to discuss long term trends more weeks of data would be needed, but this piece of analysis exemplifies the potential that this type of study has to understand, through simple statistics, behavioral trends in the workplace.



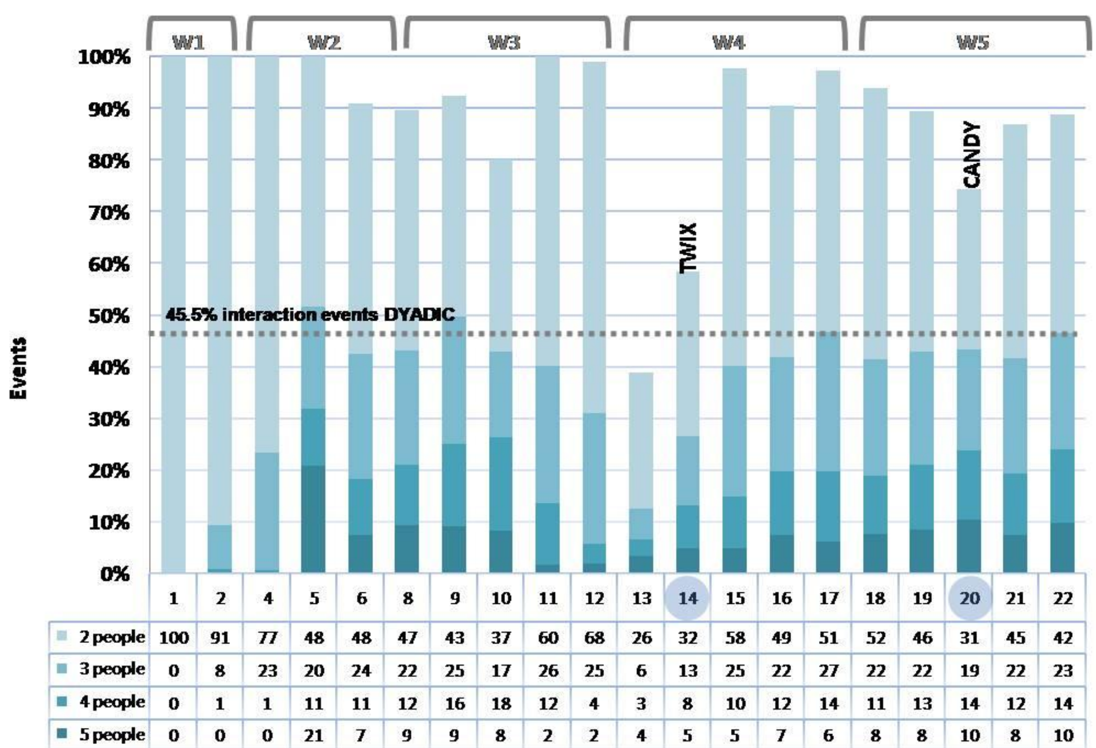
	1	2	4	5	6	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Interaction time	9	2	1	5	7	14	2	22	14	24	4	2	2	3	4	5	3	2	1	3
Solo time	3	2	3	15	11	18	15	12	18	22	12	5	4	5	5	9	5	3	4	10

Figure 8.11 Average minutes spent in interaction and solo events, per day, through the period.



	2	3	4	5	6+
Interaction Events	46.7	21.2	11.3	7.6	13.1
Time	58.1	19.7	10.1	6.1	5.9

Figure 8.12 Percentage of face-to-face interaction events vs. percentage of time spent interacting per number of participants.



	1	2	4	5	6	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
2 people	100	91	77	48	48	47	43	37	60	68	26	32	58	49	51	52	46	31	45	42
3 people	0	8	23	20	24	22	25	17	26	25	6	13	25	22	27	22	22	19	22	23
4 people	0	1	1	11	11	12	16	18	12	4	3	8	10	12	14	11	13	14	12	14
5 people	0	0	0	21	7	9	9	8	2	2	4	5	5	7	6	8	8	10	8	10

Figure 8.13 Percentage of face-to-face interaction events, per day of deployment, per number of participants.

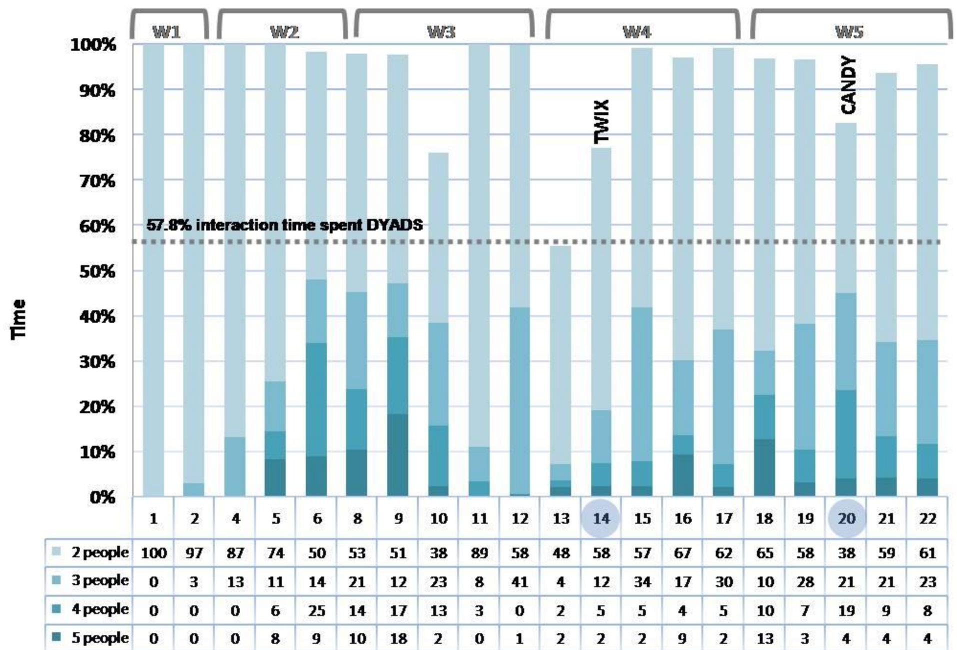


Figure 8.14 Percentage of time spent interacting, per day of deployment, per number of participants.

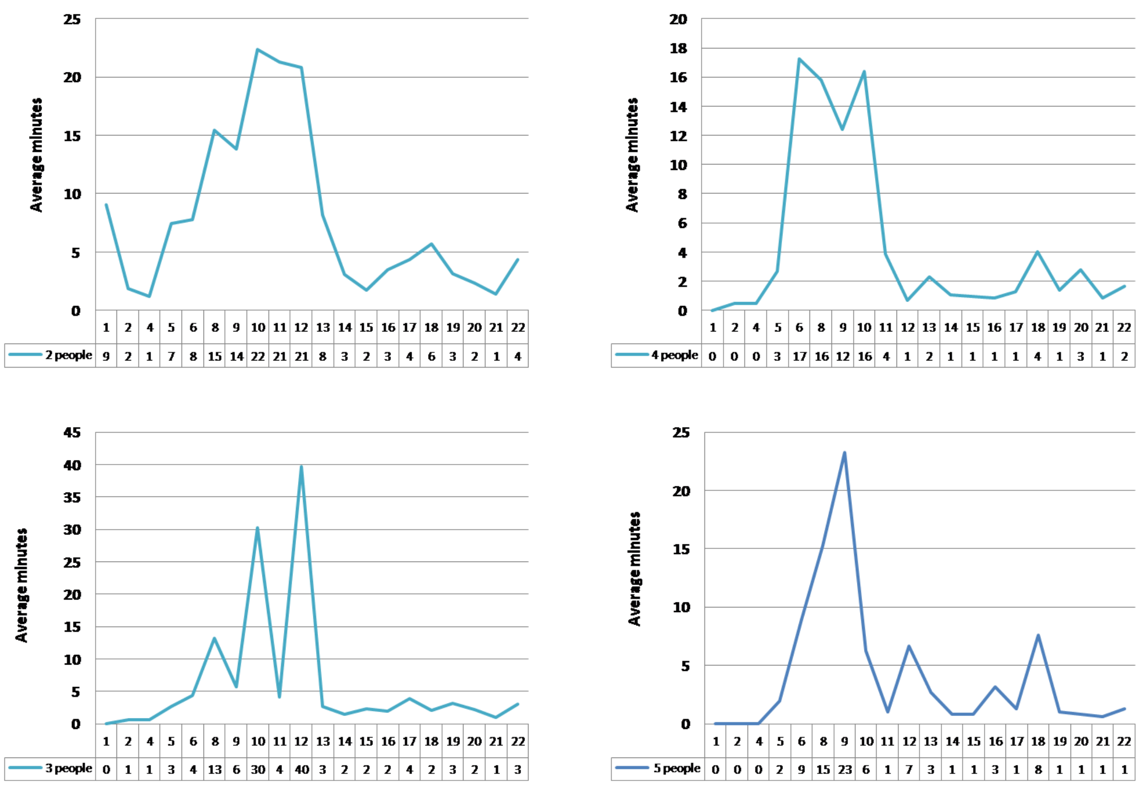


Figure 8.15 Average minutes spent in interaction, per day of deployment, per number of participants.

8.5 Face-to-face interaction: participants and duration

Having described how workers spend their days through changes in the volume of interaction and solo events and in the amount of time spent on those states, a more focused analysis examining the number of participants involved in face-to-face interaction events and the amount of time they spent interacting, presents a different angle to interpersonal dynamics in this office environment. After an initial scan of the MATLAB manipulated data, it was decided to limit the initial analysis to group sizes of 5 people. There were two main reasons behind this decision; first, the observations conducted in the deployment area didn't identify groups of people bigger than that; and second, previous research presented in chapter 3 suggests informal face-to-face interaction tends to be dyadic, and that groups bigger than 5 tend to interact formally rather than informally usually being pre-scheduled and with a designated room for the meeting. It is necessary to point out that previous research in face-to-face interaction has focused on two people more than on multiparty interactions because of the high cost involved, both in terms of the number of observers required and cognitive attention needed to record big complex events. Also, research on small groups has tended to focus on their interaction dynamics as a group with an objective, more than on the multiparty spontaneous formations this thesis is exploring.

The relationship between the number of participants in face-to-face interaction events and the duration of those events has been analysed. Figure 8.12 shows how both volume of interaction events and the proportion of time spent face-to-face declines with number of participants. Dyadic (two people) events account for 45.5% of all occurrences and occupy 57.8% of the total interaction time. The graph also shows how 2 people events, compared with multiparty ones, seem to be less numerous but take up more time, and the analysis indicates that the amount of time spent interacting face-to-face decreases with the number of people involved. When two people interact, they spend more time on the event than when 3 or more people engage on it. This is in contradiction with current research findings that assert that the higher the number of participants the longer the event (H3), but this also could be a characteristic of this specific work environment. A closer analysis of the amount of face-to-face interaction events by number of participants throughout the period and on the amount of time spent in face-to-face interaction events confirms these findings. See figures 8.13 and 8.14. It also shows the variations through the period caused by social and technical issues discussed in the previous section.

An analysis per time band of number of participants in amount of face-to-face interaction events shows that events tend to be brief, concentrating on the briefer time bands – under 2 minutes, which is consistent with the analysis presented in the previous section. See Annex J Location tracking data analysis for details.

The average duration of face-to-face interaction events in this office is 6 minutes. An analysis of the mean duration per number of participants on the interaction event is of 8 minutes for 2 person interactions, 6 minutes for 3 person encounters and 4 minutes average for 4 and 5 person interactions. A further analysis of these numbers per day of the deployment demonstrates that those days with fewer readings throw higher averages and also a trend to decrease through time. Again, more data would have permitted a more grounded understanding of the variation of duration of multiparty interaction events. See figure 8.15.

8.6 Location of events: time, type of space and visibility affordances of the office environment

The visualisation of location, duration and number of participants involved in behavioural events is one of the most appealing aspects of the use of location and time technologies in organisations. The potential to add the spatial dimension to the analysis increases its value, for the visualisation of social and physical elements of a certain space over time, provides additional insights and information not previously considered (Steinberg and Steinberg, 2006). GIS software is used in this section to take advantage of the unique opportunity to use highly accurate location tracking data to link interpersonal temporal dynamics with their location. As mentioned previously, it is not so much the information obtained through the location system as the richness of spatial analysis and the arguments that can be built on that information that will be explored in this section. GIS not only provides a unique lens through which to examine the patterns and processes that concern this thesis (de Smith et al., 2007), it also helps to critique the dataset and the overall potential of the automated method.

Three types of visualisations are presented and discussed in this section: images of preferred interaction and solo event locations through the period; illustrations of duration and volume of participants of interaction events on one particular day of the deployment; VGA analysis presented in the previous chapter and compared with the visualisations produced in this one.

In order to visualise the location of interaction and solo events, an analysis of the total amount of time that all tags spent in a particular X,Y cell, either in interaction or alone, has been completed. In order to do this, a grid of 56 cells (X axis) by 50 cells (Y axis) that covers the two areas of the technology deployment was used. Each cell has a size of 0.5 metres. The area is a rectangle of 28 by 25 metres, which is bigger than the deployment region, which was composed of two irregular polygons. See figure 4.5. The results are presented as a grid analysis of the total values obtained per cell through the period, using equal cell count of the percentage obtained. The analysis is made in MapInfo Professional. See figure 8.16. The graphs show preferred locations per type of event through the period. It is very interesting that face-to-face interaction events seem to take place at individuals desks and gravitate heavily towards the drop-in area (see figure 7.17 for details of type of work areas in the case study office environment) whereas preferred locations for solo time seem to be definitely desks, assigned fixed positions. Overall, interactions seem to concentrate and take place in a smaller section of the open plan, and solo events draw well the furniture distribution. In the solo visualisation, figure 8.16, the green colour corresponds with the circulation patterns observed in Chapter 7, see figures 7.20 and 7.21. It could be argued that people spend less time on their own, presumably walking that they do at their desks, and that the accumulated time in those cells reflects patterns of movement in the office environment. One thing that stands out in both images is the lack of activity registered in the semi-enclosed senior management offices. Manual observations indicate a fair amount of activity in the area so this exemplifies one of the consequences of that area being built out of metal: that the technology did not perform well and therefore there is no recording of events.

Figure 8.17 presents four different images visualising various durations of interaction and number of participants. These analyses are based on 28th June, day 14 of the deployment. The two top images show where 1 minute and two minute face-to-face interactions take place in the deployment area per number of participants. The two bottom ones show dyadic interactions per duration of event. The specific locations shown illustrates that interaction activity takes place mostly in or around desks and drifts towards the drop in area surroundings. This can be partially explained by the fact that those drop in tables were occupied by different people every day, highly mobile workers that only came into the office to catch up and hold formal meetings with colleagues. The analysis of a day of interaction activity shows as well the difficulty of presenting the data for long periods of time. One day is just manageable visually and cognitively. Because each event has a precise location associated with it, overlapping events, let's say for a week, present a collection of data that increasingly decreases in meaning. A solution would be analyse by grid cells, as it has been done before, but precise location of events is lost then. An analysis per desk and type of work area would be useful, but again, the granularity and precision of the location time data is discarded, and once discarded, the same information can be obtained with current methods of space use occupancy.

The VGA visualisations presented in the previous chapter, see figure 7.22, are used as a backdrop to compare the potential of the analysis proposed. Visible coawareness and copresence have been found to be the base in which particular patterns of encounter and interaction may develop in the workplace (Rashid et al., 2004). The specific measures related to interaction and privacy in the workplace, namely visibility integration, visual control and visual controllability, were described in Chapter 7, as well as an analysis of the office layout visibility characteristics. The first thing that needs to be pointed out is that, in this case study, both cells of the deployment area are placed in the layout where the VGA analysis shows higher values of visual integration, visual control and visual controllability. This can lead us to think, on one hand, that the results obtained in this chapter might be an effect of the visibility affordances of this particular part of the office environment. That is, people in places with high integration ,control and controllability, have higher visual access to the rest of the office, higher visual control at knee-level – seated, and where visual control of others is easy, tend to register more interaction activity. The segregated areas shown by the VGA analysis, where solitary work and some types of interaction are favored, are not inside the deployment area. Nevertheless, solo time is registered particularly at individual's desks. The quality of the solitary time (usefulness of the time spent solo in relation to the accomplishment of specific tasks) cannot be assessed with this method, only registered by duration and location, but it is clear that it takes place in an area that is spatially good for informal interaction and in an area that is an open plan design. An explanation could be that these individuals require a good deal of interaction with others to carry out their daily tasks. They spend brief periods of time alone and have many interactions that take place at their desks or in their surroundings. Also, the rest of the office environment not included in the deployment area provides meeting rooms and flexible quiet working areas on a drop in/first come first served basis, (see figure 7.17 for details of types of working areas), where individuals can retreat for uninterrupted, visually and acoustically private work periods.

Chapter Eight:
Automated observational measurement of interpersonal spatio – temporal dynamics in the workplace

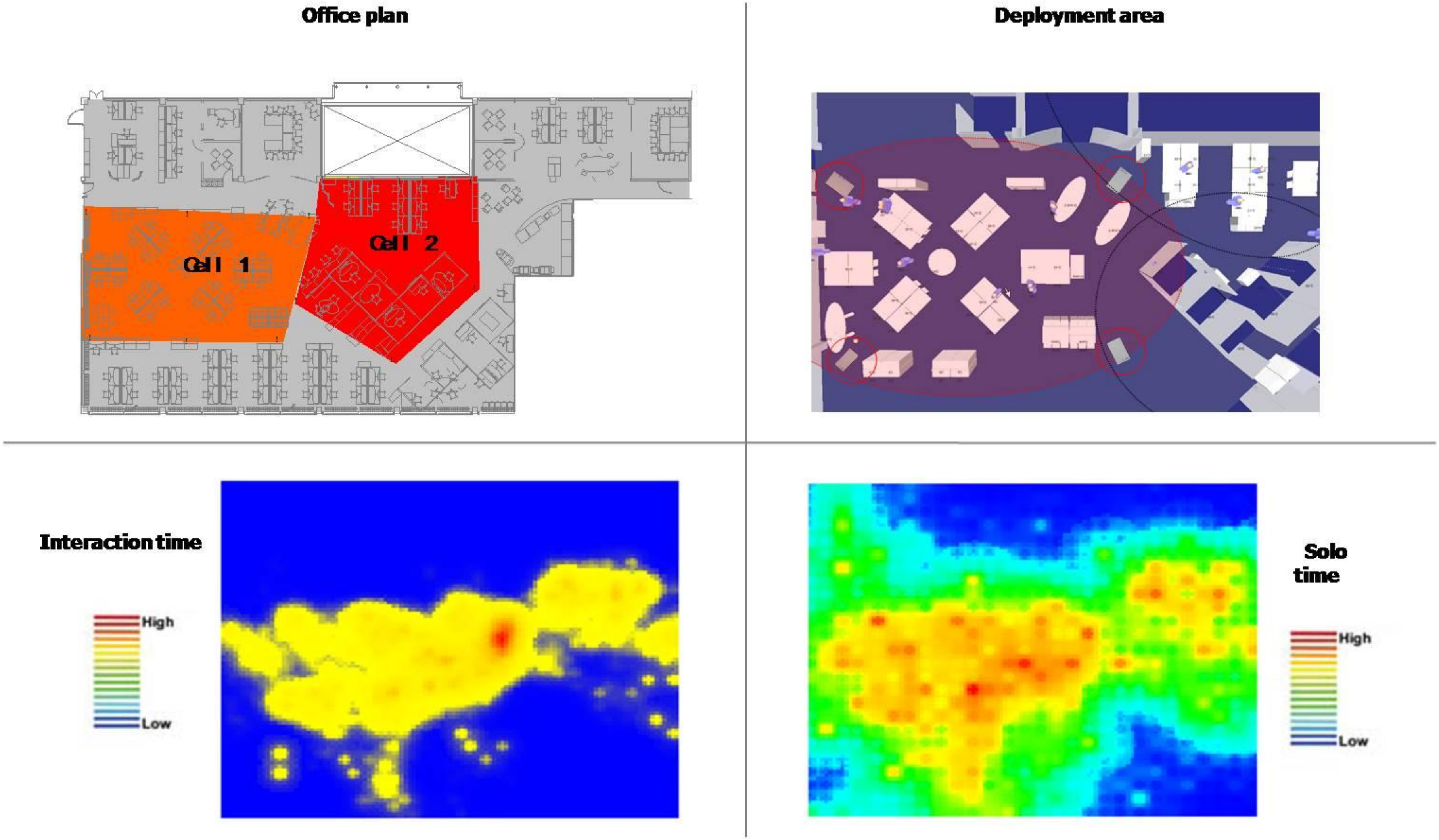


Figure 8.16 Visualisation of total amount of time spent on interaction and solo events through the period in the deployment area.

Figure 8.17 Visualisations of interaction time and number of participants, day 14 of deployment.

Chapter Eight:
Automated observational measurement of interpersonal spatio – temporal dynamics in the workplace

8.7 Summary of findings

The analysis portrays interpersonal dynamics as an interplay of interaction and solo behaviours. The detail with which these have been described cannot be achieved through the methods described in the previous chapter. All of the hypotheses proposed in Chapter 4 but one has been upheld (H3). Findings have also refined all of the hypotheses providing new, more detailed information that can be used as new hypotheses in further research studies.

Findings, regarding H1 and H2, support the premise that workers spend variable portions of their working days interacting face-to-face and in solitary activities and hold up to previous findings related to the amount of time spent in each activity. Overall, workers in this study have a higher number of solo events than interactions and spend much more time alone than interacting with others. Face-to-face interaction events tend to be briefer than solo events. An analysis per time band shows that most interaction events fall in the under 2 minutes categories versus solo events where most fall in the under 5 minutes duration. Also, mean interaction duration throughout the period is 6 minutes for interaction events and 9 minutes duration for solo events. Interaction events last for 6 minutes versus the 9 minutes solo events take in average throughout the period.

Regarding H4 and H5, speculating about the relationship between location of events and amount of time spent, findings support a positive relationship. Location affects the amount of time spent on interaction and solo time, albeit in different ways. Visualisations of amount of time spent on interaction and solo events throughout the period show preferred locations of activity as desks and the drop in area. Furthermore, illustrations of duration and number of participants confirm these results but their visualisation through time has proven to be a difficult unresolved challenge. Overlapping the visibility analysis of the layout on the location and time results reveals a good match between visual affordances of the office and interaction patterns. It is worth mentioning that the deployment area falls into the highest visibility integration, control and controllability areas of the office layout.

Hypothesis 3 is the only one that has been rejected by the findings. Knowledge workers *do not spend more time interacting face-to-face the higher the number of individuals in*volved. Findings reveal that most interaction events are dyadic and most of the interaction time is spent in two person encounters. But mean duration of informal interaction per number of participants shows that the smaller the number of people involved the higher the amount of time spent interacting. 2 person interactions take 8 minutes, whereas 3 people take 6 minutes and 4 and 5 person interactions take an average of 4 minutes each. This finding is very interesting, for it contradicts current findings on interaction behaviour in the workplace. It must be highlighted that previous research has focused on more formal meeting types when studying this particular behaviour. In that case, meetings last longer the higher of number of people involved, which is probably due to the difficulty to getting to an agreement with higher numbers. In informal face-to-face interaction, it seems that the opposite phenomenon occurs; dyadic exchanges tend to last longer probably because they are an excellent vehicle to discuss, agree, exchange information efficiently.

For this analysis only interactions of more than 15 seconds, and solo events of more than 10 seconds are used in the analysis. Time bands have been created every 30 seconds and both types of events have been classified by them. It is possible to segment interactions by number of participants, the amount of time they spent together and the location. The analysis presents work as characterised by its solitary nature. Workers in this study, overall, hold a higher number of solo events than interactions and spend much more time alone than interacting with others. Face-to-face interaction events tend to be briefer than solo events. Most interaction events are dyadic and most of the interaction time is spent in two people encounters. The smaller the number of people involved in the interaction the higher the amount of time spent through the period. Interaction and solo events happen at desks and the drop in area of the office environment, which have high values of visibility measures. These results prove the potential of the automated method to identify and record, segment and represent interaction and non interaction behaviour in spatial and temporal detail. They add another dimension to behaviour observations and self reported activities by allowing for micro observations of behaviour. The hypotheses on workers behaviour have been answered and, in some cases, extended and refined, see Chapter 9 for further discussion. Additional challenges to be resolved in future investigations have risen as well and are presented in the conclusions to the thesis (Chapter 10).

Key Points

- The location tracking system is a measuring instrument whose output dataset needs to be refined and interrogated mathematically via a coding scheme so as to identify and record behavioural states in space and through time.
- Technical, social and spatial issues reflect on the location tracking dataset and, consequently, on the recording of behavioural events. The number of tags worn through the deployment as well as the amount of time the system was functioning affects the final readings, independently of technical issues occurring.
- Only interactions of more than 15 seconds and solo events of more than 10 seconds are used in the analysis.

- Hypotheses 1, 2, 4 and 5 have been upheld. Hypothesis 3 has been rejected. All of them have been refined, information that can be used in the form of new hypotheses in further research studies.

Notes

[1] Accuracy, precision and quality of the dataset used in this thesis were discussed in Chapter 4.

[2] It is worth noticing that these codes have been developed for a particular project, in a particular organisational context, in a particular physical environment.

Chapter Nine: Discussion

Abstract

This thesis has been driven by evidence suggesting that space and time information can be used to define and therefore measure face-to-face interaction dynamics in the workplace. The possibility of putting location and time technologies together to test precise behavioural hypotheses has been tried in the previous chapter. Here the wider theoretical implications that such a test involves and a comparison of the automated and manual and methods are discussed. Finally, the organisational, design and technology implications of the research are presented, paving he way for the next chapter, conclusions.

9.1 Introduction

This thesis is an experimental exercise in understanding aspects of the relationship between people and their work environments using new technology with capabilities for precise indoor location and tracking. How can location tracking technologies contribute to the understanding of face-to-face interaction in the workplace? Is face-to-face interaction an issue of interest for organisations today, and if so, why?; Is it possible to measure it, and if so,how? What are the methods used and are they successful? Is there research attempting to measure interaction in the workplace and has it achieved something? Is it possible to locate and track people inside buildings? Is there evidence that the type of data produced by such technologies can contribute to cover the gaps identified? These are the key questions the thesis has carefully examined, culminating in the identification of significant information in the study of physical interaction behaviour in the workplace and applying it to the development of a new method with the aid of newly available data.

Organisations today place an enormous importance on face-to-face interaction for reasons that link it to the knowledge and innovation management processes without quite being able to measure it and make the connection to specific organisational performance indicators. Measurement is a key issue for managers and facilities managers alike and one that is largely missing in theory and practice.

Precise spatial and temporal information can be used to measure physical interaction dynamics. The lack of data obtained from real environments coupled with the inability of existing methods to gather information at the level of detail required justifies the development of a new method. Indoor location and tracking of devices is today a real possibility. Still, there is a lack of applications and means to analyse and display the vast output datasets obtained. The measurement of physical interaction dynamics in the workplace is a problem that can be faced with precise location and time data. But the access to such data presents further difficulties that need to be considered. These combined challenges have been the main focus of the thesis.

In parallel, existing methods have been used to understand the link between workplace features and interaction patterns, as well as the effects that the physical deployment of a location tracking system has on different levels. The objectives of this part of the study are, on the one hand, to contextualise spatially and socially the findings of the new method and, on the other hand, to provide a benchmark for its academic worth and significance.

9.2 Theoretical discussion

The results of the automated method of analysis prove the unequivocal superiority of the combined use of precise location and time data to capture, record and analyse physical interaction and solitary time events. The data obtained is invaluable in the assessment of workplace design environments and work processes and practices. It is arguably a solution that once implemented can aid the monitoring and detection of fluctuations in the structure of encounters and solo moments providing a revolutionary tool to intercede in real time when and where those red flags rise. This achievement transcends the methodological limitations that have hampered progress in both research and practice. The location tracking system can be used as an accurate and comprehensive observer to cover the gaps that current systematic observation methods using human observers leave. What is more, it opens the door to verify empirically complex behavioural hypotheses difficult to test in real environments and monitor them through time. Questions on interaction dynamics development, evolution, stages, crisis, can be studied for the first time. The relationship of these stages with the precise location where they take place provides the spatial link between the quantification of formal and informal physical working relationships and the features and attributes of rooms, floors and buildings that is today impossible to assess for individuals, dyads, or multiparty events at the level of hundreds or thousands of building occupiers simultaneously. Furthermore, precise time information, layered on top of these findings makes possible the study of the regularity of events and time sequence analysis and, consequently, that dream of strategic organisational thinkers, prediction.

Findings regarding solitary time link to the concept of solitary work and its different forms. The study supports previous findings on solitary work, namely that individuals tend to do solo work at their desks and have both more periods of solitary time and spend more time on their own than engaged in interaction. To be able to measure solitary events is essential to understand the effectiveness of time use at work, contemplating the interdependence of solo and interaction patterns both for an individuals' perspective and for groups of workers. Automated quantification of these relationships is a great achievement, but numbers give only part of the picture. The measurement can point to individuals engaged on high cognitive, solitary work but it can also point to (whilst not measuring) "covered" periods of furious interaction activity using e-mail, social networking sites, chat, video calls, blogging, tweeting…. All courtesy of ubiquitous blanket internet connectivity in many of today's workplaces. Not long ago being on one's own was perceived in the workplace as a good habit, solitary time implying getting work done (Webber, 1993). Today the trend has perhaps inverted, and it is ironic to think that talking to others might be perceived as "proper work" while solitary time could equate to "doing nothing". This point is also related to the choice of media for communicating with others at work and for getting work done. Workers today need to combine and integrate multiple media such as e-mail, texting, instant messaging or video calls, in their limited 8 hour workdays. This leads to frenetic activity in order to use these media to get work done. These communication chains can be masked by what is otherwise labeled as solitary work, when in reality is a frantic race to get work done.

Finally, these results contribute to the scarcity of findings on interaction and solo behaviour in naturalistic environments supplying new evidence against which to test and compare further research in this area, information in which to base decisions on the design of work processes and structures and the buildings that accommodate them.

The results of the manual methods of analysis in chapter 7 contribute to the thesis in two different ways. The analysis of activities and movement patterns in the workplace provides information that aids the establishment of an adequate interaction distance for a specific context. Culture – both country related and organisation specific – as well as spatial layout and distribution, affect interaction distances and gathering information of existing activity patterns is a fundamental requisite to confidently calibrate this metric. This type of analysis also contributes to the thesis in that it establishes the benchmark of what is usually done in the workplace research and consulting arenas in terms of measuring interaction and work activities. This point is further pursued in the next section.

The results of the interviews highlight a number of aspects that cannot be captured by the technology, specifically its effects on the spatial and social work fabric. What initially started as an exploration of attitudes and perceptions towards a technology labeled as intrusive, uncovered a wide range of issues with implications for designers, managers and technology developers.

Findings suggest that trust in the organisation's management is essential for the acceptance of the technology; that the temporary nature of this particular deployment eased considerably its acceptance by staff; that the lack of immediate personal benefit negatively affected the perception of the usefulness of the deployment; that workers' perceptions of the general scope and objectives of the technology were influenced by sources external to the organisation itself, such as the media; that wearing the tag was perceived as a nuisance, but this perception diminished through time, probably influenced by the temporary nature of the deployment; and that individuals developed behaviours around wearing the tag that best suited their habits, disregarding formal efforts for staff to wear it efficiently. These qualitative findings constitute a check list to contemplate when planning and executing deployments in real environments. Organisations, technology developers and IT companies participating in such processes should take into account three main areas: the existing relationship between management and staff; the deployment duration and the deployment time-frame.

Building on existing relationships of trust between management and staff should be a factor feeding the introduction of the technology. Trust facilitates the discussion of the potential value and benefits for both parties and eases the communication process. Good communication contributes to understanding the technical scope and avoids misunderstandings that can lead to situations of mystification of technology, which is harmful for success.

The intentional temporality of a deployment can serve two different purposes. First, workers tend to accept it for they perceive it as provisional and not for real which avoids unnecessary tension in the workforce. Second, a temporary deployment can be a first step to build a business case, assess the potential disruption to work (including learning demands) and existing layout and spatial distribution, and detect further and unforeseen technology requirements. Complex building layouts and metallic materials can affect accuracy greatly, not only at the moment of the deployment but also unanticipated future changes in décor, furniture, partitions andthe performance of the technology.

Independently of opting for either temporary or long term deployments, a transparent, “slow growth” approach, where there is a phased introduction of new features that help planning for unexpected and unintended behavioural consequences, can ultimately assure its success (Konomi and Roussos, 2007: 519). Possibly one of the most harmful attitudes that can be found in a workplace and in organisations as a whole, is the creation of myths and rumours and the consequences it has for the success of any change implemented in them. Also, the perceptions, understanding and physical routines of the users of the system have an impact in the data collection and ultimately on its usefulness. Knowing that behaviour affects data collection, design of the capturing process can be informed and a solution to these problems can be attempted. Issues raised by unanticipated reactions and their consequences in the day-to-day running of a business are difficult to assess in laboratory based studies.

Organisations and technology companies alike should be aware of the problems that raising expectations towards the capabilities of the technology may present when it comes to successfully finalising a deployment.

This body of lessons learnt support and advance existing advice on social aspects of pervasive deployments in real environments (Steggles, 2003; Konomi and Roussos, 2007). Together they constitute a corpus of guidelines providing advice on social and spatial issues mostly outside the scope of current pervasive computing and organisational research and practice, which nonetheless play a critical role in real life deployments.

9.3 Methodological discussion

A key issue emerging from this research is the assessment of the new method over existing ones. All of the methods used, the automated and the manual, have both advantages and disadvantages of their own. These are discussed in relation to three sets of issues: the data gathering process, the data sources and datasets obtained and the nature of the findings. The argument focuses on presenting evidence on how each methodological approach contributes to the measurement of interaction and solitary events through time. VGA analysis is considered in the last point 9.3.4.

9.3.1 Process related issues

There are a set of issues related to the data gathering process and to the deployment of the technology and the human observers. The advantages of the automated method reside on the potential of the location tracking system of gathering location and time data for a large number of tags simultaneously and continuously for long periods of time. Current manual methods to study interaction dynamics in organisations are deficient in providing a comprehensive picture of the spatial and temporal characteristics that delimit and define these dynamics. But the manual and other methods employed in this thesis – observations, interviews, survey, etc – have the advantage of being flexible, easy to set up, of widespread use within the workplace industry and less expensive than the technology used in the case study.

By contrast, the technology deployment is expensive and highly complex to set up, although technological developments are likely to see this change in the future. It also potentially brings a set of, often overlooked, spatial and social problems related to features of the physical environment (i.e. ubiquitous presence of metal in the case study office environment) and to people's perceptions, attitudes and behaviours (i.e. fears of privacy invasion or of forgetting to wear the tag). See figure 9.1.

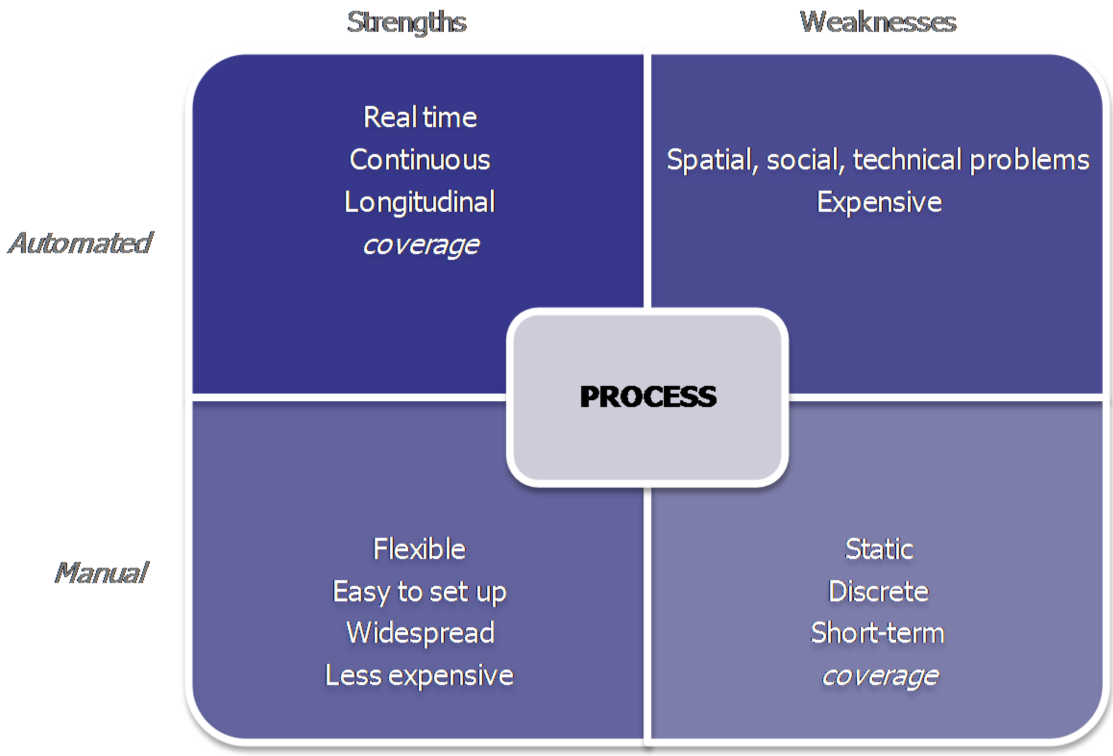


Table 9.1 Automated versus manual methods: strengths and weaknesses related to process.

9.3.2 Data sources and datasets

The new method transforms millions of location-time data points into thousands of relatively manageable, more focused pieces of information (events), information that needs to be further manipulated and compared with other sources to make practical use of it. To illustrate this point the thesis' case study comprises 51 individuals wearing tags that update their location in the office environment every second. 1 day of data, for 51 tags, for a working day of 8 hours, throws potentially – provided that the system works and that all inidividuals wear the tag - 1.468.800 location points (format Cartesian Coordinates x,y,z data points). Excel 2003, the most widespread data organisation and manipulation spreadsheet software, has a capacity of 65.000 rows on a worksheet and Excel 2007 has over a million rows. Without the MATLAB program and the coding scheme to lead the manipulation of the raw data, the outcome dataset is extremely difficult to manage.

The issues related to the data sources are connected with the reliability of the observers and of the technology used as observation tool. This has an impact on the result datasets, affecting the outcomes. The location tracking system is a measuring instrument whose output dataset needs to be refined and interrogated mathematically via a coding scheme so as to identify and record behavioural estates in space and through time. Because the source is precise recording of location and time, the outcome is a comprehensive and systematic record of events with data with little room for ambiguous interpretation – Cartesian coordinates, number of seconds engaged on an event and number of people interacting. The manual methods employed only provide partial observations of behaviour in the office environment.

It is interesting to notice how issues of reliability arise with both methods; for the automated method is about accuracy and precision and for the manual methods it is about agreement of observations. The accuracy and precision of the automated method results from its ability to calculate the position of tags worn by the participants in the study to an accuracy of 15 cm, for an estimated 95% of the time. In reality, this precision was obtained 48% of the time and varied from location to location. Various technical, social and spatial issues that appeared during the deployment process affected the reliability of the system. This reflects on the location tracking dataset obtained and, consequently, on the identification of behavioural codes and their subsequent recording. Issues such as the number of tags worn through the deployment or the amount of time the system was functioning affect the final readings and have to be planned for and dealt with. On the other hand, the accuracy of data gathered by human observations is necessarily contingent on the performance of the observers. However, even with diligent and well trained observers the use of single observers recording the activities of a number of people in a space during a single instance necessarily introduces an element of judgment into the observations – with a potential disagreement of observations - and a high cognitive cost when the interactions involve greater complexity – i.e. more people, smaller units of time and longer periods of observation. The location tracking system does not depend on judgment in the recording of events. It also does not suffer from cognitive overload. The analysis of the interaction and solo events depends however on the inference that when peoples' personal spaces intersect for a defined period of time interaction is taking place. While this assumption is supported by previous research, further investigations into the validity of this inference using the technology are needed. In future case studies this could be done by simultaneously using human observers and a location system to measure a multitude of different events and by cross checking the data from each source.

The manual methods used produce manageable amount of data that can be processed with relative ease. By contrast, location tracking systems provide a vast set of data points - the Ubisense system was calibrated to update and record position 4 times a second – and the processing of the raw dataset using the coding scheme still throws a very large amount of data. Whereas this is a clear strength of the method, the sheer volume of data makes it difficult, firstly, to comprehend and think around it, and, secondly, to manage. Also, while observations, interviews and surveys have plenty of literature and examples on how to deal with the outcome datasets there are no off-the-shelf tools to deal with the raw dataset, and so the coding scheme was developed. See figure 9.2.

9.3.3 Quality of findings-related issues

The automated method developed in this thesis makes a unique contribution to the study of observable behaviour in organisations. For the first time highly precise location and time behavioural hypotheses can be investigated in a real environment. The findings in this thesis present fine grain information on the precise location, time, and composition of interaction and solo events. This new information opens a door for the formulation of new questions and the development of new applications. Posing new questions requires us to think differently, in order to understand the structure of the data process and the types of findings searched for. There are currently no frameworks to input this information into business strategy, workplace design or technology design, as there are no standard ways of displaying this type of information. For example, temporal aspects of work are not usually included in management decision making or design decision making and thinking of work as a state of flow between interaction and solo states is not commonplace in business thinking.

By contrast, the results of manual method are easier to input into the different decision making processes affecting the organisational structure, design and technology. The use of human observers allows the recording of a different range of variables than the location tracking system, although providing coarser spatial, temporal and behavioural information in return. See figure 9.3.

9.3.4 Reflections on the study of physical interaction dynamics

Studying interaction in organisations calls for a multidisciplinary and multi-method approach. Examples abound in the literature of empirical studies on the topic, but there is also a clear need to explore the less objective aspects of interaction. The truth is that no tool will suit every need when investigating the multiple complex aspects of behavioural dynamics, but ideally combinations of tools – such as the ones proposed in this thesis – can be paired to achieve the understanding of spatial and temporal issues sought. At the same time, not all organisations will need the same approach

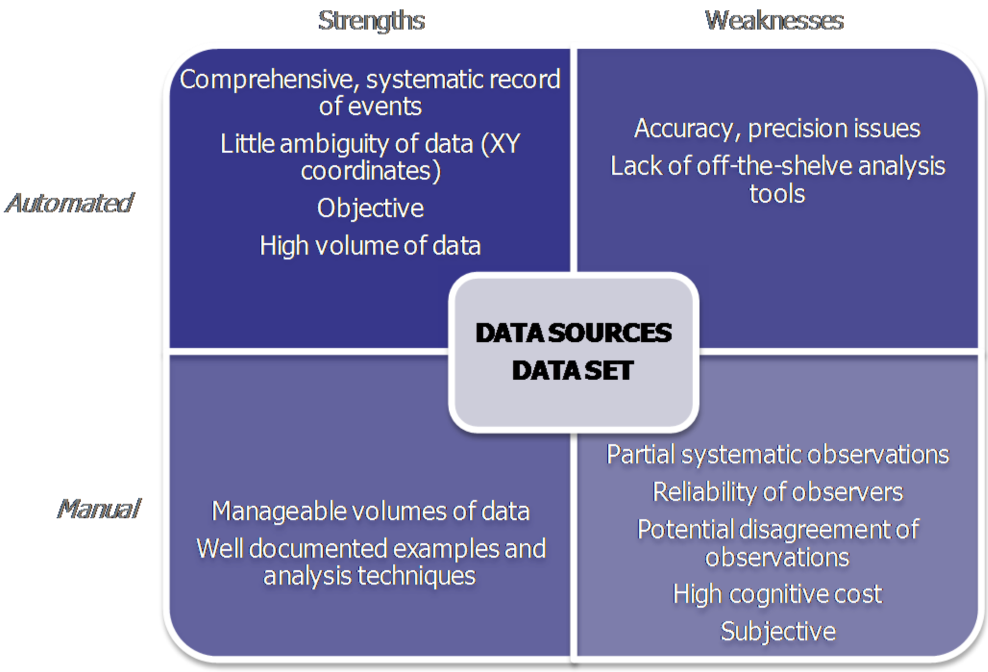


Table 9.2 Automated versus manual methods: strengths and weaknesses related to data sources and data sets.

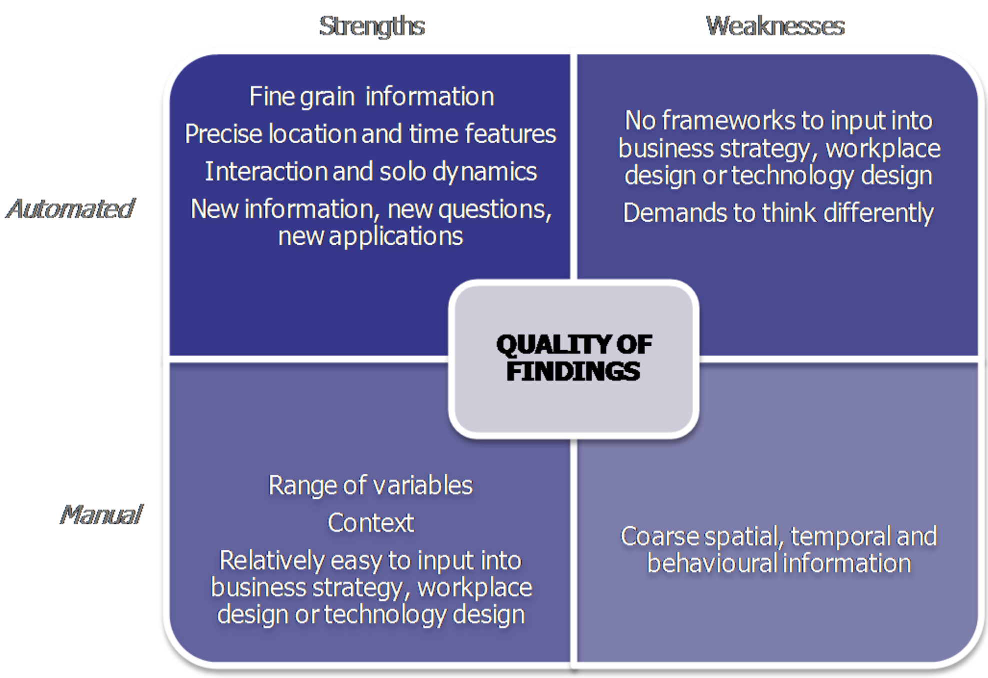


Table 9.3 Automated versus manual methods: strengths and weaknesses related to the quality of the findings.

to measurement for their culture, building layout and work rhythms are bound to differ.

Some aspects of workplace dynamics can be, up to a point, objectively studied: utilisation, occupancy, work style. But many others escape the realm of the scientific method and previous research shows that a qualitative, experimental approach may be more adequate to study issues that link together such as culture, spatial culture, informal interaction spaces and dynamics or interaction types. Analysing an individual's activities makes sense only if you are looking to identify that particular person's behaviour with a particular purpose (i.e. to understand time use at interpersonal level dynamics and relate this information to place – does that person spend the time where he/she is supposed to be doing it?). This information can be compared with role, type of job or social network analysis if the company does that, and so really tailor that person's spatial and temporal circumstances affecting his performance. Arguably, this could be used to coach individuals, make them aware of their strengths and weaknesses, very much in the line whith the way that some of these location technologies and mobile technologies are being sold, to self monitor behavior, although there is a clear threat to personal privacy that needs to be factored in.

At the same time, the most intangible aspects of building design, that in this thesis have been studied partially through the analysis of visual affordances of work environments, are an invaluable source of information to understand how buildings work socially. What one can see, facilitated by means of physical boundaries or the lack of them, affects how offices work spatially. This information affects individual decisions towards what to do next, either where to go, who to talk or where to retreat. In this particular aspect, recommendations point towards the inclusion of such analysis at early design stages to assess how different proposals enable and encourage different behaviours.

9.4 Organisational, design and technology implications

The practical implications that the findings, reflections and comparison described above have for managers and facilities managers, technology researchers and workplace designers, relate to the way of thinking about and approaching managing people and buildings and developing technologies. The wealth of data produced by these systems poses managers and designers with new questions and the use of new methods to incorporate into their work. It opens up possibilities for experimentation for innovation involving people and the environment, but also presents challenges that have to be considered.

The most important innovation management practice opened is experimentation aimed to understanding operational changes in real time. This possibility to explore the intangible qualities and connections between design and management can lead towards its business measurement. For intuition alone is not a sufficient reason to invest time and money in the refurbishment of an office, nor in the initiation of an organisation-wide change management process. Neither should it be the only cause to drive an office design. Facts, evidence andsupporting insights of what a business and its spatial counterpart needs based on the behaviour of the building occupiers and workers' patterns are essential to make those decisions (McLennan, 2000). Management, design and technology are links in a chain of inter-related organisational innovation influencers and their relationship poorly understood. Buildings accommodate organisations and enable them – using management, design and technology strategies – to meet their core purpose. Focusing attention on one of these aspects alone is insufficient to understand innovation or productivity of the workforce of the organisation. The alignment of these strategies has proved, in the past, difficult. These disciplines, in theory and practice, have been cut off from each other in different ways. Design has reflected management ideas but has been considered mainly a cost cutting strategy more than a wider business consideration. The type of technology regarded in this thesis is barely starting to be even a real possibility for most businesses There is a need for effective systems to identify and react to the continuously changing needs and perceptions of occupiers that can be filled using them to experiment with and measure these previously intangible aspects. With similar technology and methods, organisations and designers can benefit from a continuous flowing picture of workplace dynamics, and the transformation of organisations over time can be observed, assessed and predicted provided enough data has been collected.

In addition, the method developed can be transformed into a measurement, management and predictive tool. There is no doubt the analysis of the location data can be taken much further than has been attempted in this thesis. Further statistical modelling as well as further spatial calculations combining visualisations of the syntactic properties of layouts and the precise temporal and spatial data obtained are a research path to be further explored. Behaviour is regulated by processes (McGrath and Kelly, 1986), therefore if behaviour can be understood through time it will be possible to predict it, identify variations and propose interventions to correct it. In this sense, sharp fluctuations of behaviour affecting the typical readings/balance, can flag early warnings to the organisation, information that can be used to prevent situations.

This can also be done at different levels (i.e. group manager, area manager) that can act upon the information and observe collective workers' response immediately. Managers might know of ongoing work problems, know that a change is needed but not be able to identify it. They might even know that it is related to personal exchanges – an excess or lack of them – but it cannot measure what is wrong, and therefore, cannot correct it.

However, a word of caution is called for. These types of technology systems, pervasive or ubiquitous, when introduced can be potentially disruptive not only for users but also for other systems already in place and the impact on current organisational infrastructure and practices must not be underestimated. The study suggests that pervasive computing research should view its applications as situated within an organisational environment as a realistic context for the research and development of products, a real life framework to be taken into account along with the needs and constraints created by the real world. Other deployments of similar technology, such as RFID systems, point to the need of planning for organisational changes to be put into place before even considering the deployment of those systems. Just the sheer amount of data produced places great pressure on the parts of the business in charge of information management and delivery and on the managers and facilities managers themselves. The new data streams need potentially new training in systems that allow the internal dissemination of results in a meaningful way and so some of those constraints can be avoided (Konomi and Roussos, 2007), but they also need to take into account that the range of expertise needed to make use of the information is usually not found in any one single person.

It is a basic assumption of this thesis that organisations are particularly interested in linking the design of their buildings to the work activities taking place within them in order to allow them to design better buildings and use existing ones more efficiently. It has been pointed out that typical organisational strategies to encourage interaction deal with legitimisation of the act, flexibility of structures and provision of physical opportunities for encounters. Workplace designers aim to comply with management demands, translating into spatial settings management ideas on interaction dynamics. Management needs to maximise their workers' productivity, and so implement strategies that allow them spatial and temporal flexibility and choice at need (as individuals and as groups), for people price choice and transparency. In this context, where organisational and workplace design for interaction needs an alignment of business strategy, work processes, workplace design and organisational culture/s, the challenge lies in involving precise information on the location, type and timing of interactions at the pre-design stage and inputed into the design process to avoid user's resistance and the jeopardising of the project (Oseland and Willis, 2000). The best designed workplace for a company will be always very much unique and different from the next door office. Because good design will mean different things to different organisations, and will therefore, ideally take different forms that reflect business, culture, work processes and technology use. Space is never the passive background of work life, it allows for physical experimentation of layouts (Shpuza, 2006) and contexts to best suit work and interaction or solo practices. A well designed office is a very subjective concept that has to be rooted in the core organisational values and strategic considerations and that has to feed off the time and spatial features.

Today's knowledge organisations are becoming more aware of the importance of design to contribute to organisational performance through its effects on physical interaction and solitary behaviour. Temporal issues, by contrast, are linked almost exclusively to time use issues, and their impact on interaction dynamics is not contemplated. When managers are encouraged simply to promote interactions without regard to their timing and do not focus on synchronising individual and interactive activities, nor on addressing the context in which these activities do occur, problems related to the sociological phenomenon of "time famine" appears: individuals crave time, feel their days are not long enough to fulfil their tasks and have no balance between the amount and frequency of interactions and the amount and duration of solitary time.

Also, there is a perception problem in the way time management issues are conceptualised nowadays, which implies individuals can change their habits but doesn't take into account the effects on the work group and individuals' interdependent work patterns on those attempts to change (Davenport and Prusak, 1998: 80). The use of a similar technology-mediated method to capture temporal characteristics not only aims to make accurate measurements of behaviours through time, but the identification of patterns that repeat regularly, cycles of behaviour (Ibid.81). Time, as the long-time perspective, allows for the identification of cycles and rhythms that, when altered, focus attention on specific activities, places, groups of people and individuals. For all this the technology can be of invaluable help, providing the richness, longitudinal nature and objectivity that observations, surveys and self-assessments cannot.

In conclusion, the capacity demonstrated by this and other research to record fine grain location and time information indoors and use it in an organisational context affords three levels of benefits. First, the provision of quantified behavioral activity of oneself and of co-workers that can feed back into conscious decisions to improve both individual and group dynamics. Second, the availability of accurate statistics of occupancy and activity in the building, that can be related to unit, group and role, which in turn can be aggregated to compare to performance measures, measured through time and down to the second. Finally, this improved understanding of behavior in offices – naturalistic settings – creates new opportunities for development of context-aware applications (Intille et al., 2003:164). The challenge at these three levels will be to create applications that deliver tangible benefits to users, increasing opportunities for interaction and potentially, for productivity, whilst managing concerns over privacy and intrusion fears.

These, among others, are issues that arise from this investigation and that point towards a real possibility for acquiring precise and longitudinal understanding of some spatial and temporal aspects of behavior linked to performance, efficiency and effectiveness in organisations. Individuals, groups and businesses can use this information to enable personal, collective and corporate transparency, control and ultimately, responsibility for their conscious actions in this context. With the availability of technologies with capabilities for sensing human presence that can be used to measure behaviour systematically and objectively, perhaps the researcher, manager and designer should seriously consider include location and time data logs into their own work, strategies and building designs. The decisive test of this newly gained knowledge will be in its application in real environments. The plethora of new data sources and datasets will present challenges to the management and use (presentation and visualisation) of such rich information, as well as changes in behaviour and unexpected privacy implications (Roussos, 2006). The adoption of location technologies and devices with similar capabilities opens up a new era of organisational management and workplace design possibilities and challenges. This will only be achieved through further interdisciplinary research bringing together business analysts, social scientists and applications developers.

Chapter Ten: Conclusions

Abstract

Highly accurate location tracking systems can be used successfully to study in detail human spatial behavior. The great wealth of data generated by these systems can be manipulated and structured to produce meaningful information portraying the dynamics of physical interaction. In many respects particularly quantity, accuracy and granularity of data, the automated observation of behaviour, mediated through technology, presents advantages over human observation of the same behaviours. Human observation retains certain advantages over the automated observation method with respect to qualitative data. VGA analysis provides another way of looking at the relationship between space and people, with advantages over both methods. The discussion in the previous chapter leads to a set of conclusions in the area of organisational and facilities management, workplace design and pervasive computing. The identification of future research directions that could arise from the work forming this thesis closes the chapter.

The primary finding of this thesis is that it is possible to use highly precise location and time technologies to automatically gather data that can be used to measure spatial and temporal aspects of the dynamics of physical interaction. The fine grain analysis allowed by such a system enables both researcher and practitioner to formulate new questions and devise solutions to explore and understand aspects of workplace behavior that are not amenable to other forms of analysis. There is significant potential to use this information as an input into the design of workplaces, the management of organisations and the further development and refinement of location tracking technologies.

The work presented in this thesis demonstrates that the automatic gathering of indoor, real time, continuous, multiparty and longitudinal precise location and time data is an entirely feasible but complex and costly process. While the information offers potential access to unprecedented insights into human behaviour in organisations, unsolved problems related to its management and to its display, make decisions over the introduction of such technology in the workplace complex and difficult for businesses. These problems are compounded by the difficulties encountered in actually deploying these still immature technologies in the workplace.

Despite these problems the opportunity afforded by these technologies to identify, capture, measure, sustain and intervene on the dynamics that originate and maintain the knowledge exchange processes of building occupiers is real. This information could feed individuals' and groups' understanding of their own work patterns, making them aware and able to assume a different level of responsibility for their own management and accomplishment. Managers can use the variables identified in this thesis characterising and affecting the flow of interpersonal behaviour (number of people involved on interaction/solitary events, duration of events, precise location and frequency) to monitor the current interaction and solitary work patterns of staff and to measure the effects that changes introduced at different levels – organisational structure, layout, scheduling of tasks – have on them. Data on patterns of interaction could be linked to individual, team or organisational performance through analysis of the time, and hence cost, spent interacting with other team members while performing a particular process or task. Data on the sequence of activities and the time spent on each task within a process can be combined with cost information and so a model of the process can be created. Such a model can "alert managers to problems, scheduling bottlenecks or instances when the process is being circumvented" (Perry et al., 1995: 21). The development and introduction of applications focused on wider organisational performance (rather than building performance) is hampered by the absence of experience and knowledge within businesses of these technologies. This problem is compounded by the fact that the data produced by a sophisticated location tracking system cross cuts the functional division of responsibilities between IT, HR, Property and Operations commonly found in organisations. Organisations that are able to address these issues and take advantage of the potential of location tracking technologies may be able to gain a competitive advantage in the future.

To fully assess the impacts of the different variables mentioned in their multiple combinations over time, experimental deployments with larger numbers of users held over longer time periods will be required. Only once these trials have taken place will it be possible to advance a strong business case for long-term deployment. Further experimental deployments will be needed to provide data over a wider range of environments for more general conclusions to be drawn and for standardised applications to be developed. Progress in developing these technologies and applications will be inhibited if standard taxonomies of work dynamics, spaces and organisational types are not used across all experimental deployments. In conclusion, lessons learned from real cases should be accumulated and consolidated in a body of recommendations for organisations, designers and technology developers alike to take on board when thinking about multi discipline challenges. The key issue is to generate enough data to allow us to identify, monitor and detect and predict, on the one hand, the problems that both workers and the building, and its internal distribution and composition place on the deployment of devices with location capabilities and, on the other, to use the accumulated data to learn about human behaviour in buildings. The drive for using real environments and real people should be to get tangible evidence to produce specific solutions, for them to be related to the function of the organisation, the technology development, the design of the environment or a combination of these.

From a design perspective, managers should think about space as a link in an integrated process that starts by understanding what people need of their workplace to do business, and ends with an understanding of how the design has worked in practice (RICS, 2008). The environmental circumstances surrounding work that enter individual's and collective choices of interaction and solitary work are specific aspects that managers, facilities managers and designers must take into account and can experiment with. A feedback loop is needed in order to assess aspects of the design to fit the changing needs of people and the business over time. For this the technology can be of invaluable help, providing on the one hand, the richness, longitudinality and objectivity that observations, surveys and self-assessments cannot and, on the other hand, data to measure the uniqueness of each organisation, its practices and its work environment. Managers and designers alike face the challenge of managing and displaying these new datasets. Data management involves a steep learning curve and it is a process that needs to be incorporated into the organisational work processes, with the difficulties of lack of experience and authority pointed at before. This has an effect in the computing research community, for it points to the need of developing and commercialising tools that allow the presentation of complex spatial and temporal information adequately.

In this sense, there is a steep learning curve for the interpretation and visualisation of accurate and precise location and time data. Ideally, further research in this area should aim to develop applications that go seamlessly from raw location data to visualisation of interaction dynamics inside the building. The capacity demonstrated by this thesis and other's research (Pentland et al 2005, 2008) of measuring behaviour in buildings through the integration of input and output from devices part of dynamic sensor networks should be investigated further by the pervasive computing community. Sensor data information can offer a rich, objective and long-term picture of work processes in an organisation at individual and group level and this knowledge can be linked to measures of productivity. The next logical step poses the real challenge that is to work with end-user organisations to establish a series of consistent and clear questions. Informed by this understanding of what organisations want to know a robust platform, statistically sound sampling and a well thought data analysis methodology can be developed and tested over time and across a spread of offices with their users and the organisations that embrace them.

Future research directions and applications

The research and approach advanced in this thesis can be developed and extended in a number of directions. As the cost of sensors and associated technologies falls, in line with almost all IT, there will be more sensor technology available around us, either for personal use, fixed or mobile, deployed in our cities, homes and workplaces and hence more data available for analysis. Given this, and being aware that the actual application of these technologies will be undoubtedly dictated by larger forces, the thrust of future research and application development in this complex area that this thesis proposes, "is not so much one of developing new technologies as it is of developing new insights into human nature" (Hall, 1983: 186).

Four main areas for research and application development spring from this work:

- Modelling of work related behaviour in organisations;
  - Static and dynamic visualisation of that model or models;
  - Mixed method approach to the development and testing of solutions;
  - Real life long-term long scale organisational deployments.

Modelling

The modeling of behavior in real time involves the development of a business index that links detailed spatial and temporal information with performance indicators.

This model would aim to:

- Study other workplace technologies, and their use through time and how they are related to behaviour dynamics.
- Measure the duration of events, the number of people typically involved, the location of these events and to provide quantitative information on an organisation's culture, specifically on the degree of formality or informality. This information can be used to input into the design and management brief for the design of the workplace and could also be used to measure the impact of organisational change programmes.
- Provide a measurement, management and predictive tool for organisations about behavior dynamics and work flows. Further software development will allow mining the data and identifying different types of interaction and non interaction states.
- Provide predictions, classifications with the use of ID numbers to create different profiles and to differentiate/identify groups, to cluster behaviour, and potentially to predict who you are going to talk to next.
- Describe spatial and temporal behavioural cycles, in a simple and telling way, linking to organisational performance indicators;
- Create typologies of multiparty informal face-to-face interaction,
- Support micro studies of behaviour in space, involving furniture systems and open and enclosed layouts, that can provide further insights into the relationship between physical barriers,

their size, colours, materials, and interpersonal dynamics.

This model would also contribute towards the current trend of making the 'invisible visible'. That is, to make explicit to individuals their own behaviours in different environments thus providing them with the possibility of changing these behaviours.

Visualisation

The visualisation of accurate and precise location and time data involves developing tools that can display the performance indicators above described both statically and dynamically. Static visualisations address operational needs. Dynamic tools allow for strategic planning and prediction.

There is a steep learning curve for interpretation, as it has been pointed out and also for visualisation. Research in this area should aim to develop applications that seamlessly go from raw location data to visualisation of interaction dynamics inside the building.

The visualisation of preferred locations of behavior is a very interesting thing that can be done with these technologies, but the analysis presented can be greatly improved, and that is one of the research paths that remain to be explored in the future. The sophistication needed to dynamically represent behavior through time remains an unsolved challenge. This detail can be extremely useful to understand micro-use of spaces, such as furniture modules, where behavior can be measured down to a few centimeters and the analysis can be reduced to a well defined and limited environment. This is linked to the need of knowing what to ask and what to investigate in order to obtain the information required. Raw location and time data are nothing without a good question to be answered.

The dynamic representation of the results is a challenge, as well as its combination with current organisational ways of working.

Real deployments

Naturalistic, long term deployments involving thousands of individuals would enable research to put into practice strategic and design experiments and to develop and test in a feedback loop location based technology solutions. These are necessary to identify trends, typical days/weeks, to measure changes and the effect those changes have on work relations, their amount, duration, location.

Mixed methods

Today, all indoor location technology available is noisy, which results ina difference between readings and the social reality measured. When further steps are taken, and this implies the identification and recording of behaviour, qualitative tests need to be conducted to assess the difference between the readings (location data) and interactions recorded (the contextual interpretation of location data relationships). To make sure that the interpretation of data is valid, specific qualitative techniques should be employed, such as shadowing interactions or brief "interaction profiling" questionnaires. Also, the location and time data should be complemented by a qualitative understanding of the nature of work. It has been pointed out before in this thesis that the development of the coding scheme was possible because various ethnographic tools were used to explore spatial and time aspects of use of space. Without that insight the fine tuning of the automated method would not have been possible. The technology deployment needs to be planned and implemented from a previous understanding of the organisational context in all its multilayered richness. Such tools should be complemented with other qualitative tools to provide the subjective aspects of behaviour not captured by the technology to form a consulting toolkit.

The opportunities for further methodological research are very important. As technology progresses and new forms of technology are rapidly becoming available researchers will be able to capture information in very fine detail and ease the manual burden associated with empirical studies. Such possibilities are likely to develop new approaches and the exciting prospect of accessing previously unexplored research questions.

The location tracking system does not depend on judgment in the recording of events. It does not suffer from cognitive overload either. The analysis of the interaction and solo events depends however on the inference that when peoples' personal spaces intersect for a defined period of time interaction is taking place, that is, it relies on human judgement. While this assumption is supported by previous research, further investigations into the validity of this inference using the technology would be welcome. In future case studies this could be done by simultaneously using human observers and a location system to measure a multitude of different events and by cross checking the data from each source. There is a shift of focus towards higher level problems. The office will remain a place to interact, to think and gather exchange and create knowledge to get work done (McLennan, 2000).

The factors that matter most to knowledge firms tend to be the factors that are most difficult to develop: culture, human infrastructure and senior management support. All of them are human related issues. When it comes to dealing with knowledge, it is the human issues that present a higher level of problems. Data and information are constantly transferred electronically, but knowledge seems to travel most efficiently through a human network (Davenport and Prusak 1998).

We have an immature technology, coupled with unprepared human resources, lack of cross-cutting expertise in all areas and a lack of large scale real deployments. The combination of these factors highlights the importance of the person and the collective as key elements of the equation.

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