Wayfinding Situations

Ph.D Thesis

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Declaration

This is to certify that the thesis comprises only my original work towards the PhD and that due acknowledgement has been made in the text to all other material used.

Abstract

Wayfinding, which is the task of getting from some origin to a destination, is one of the primary spatial problems humans encounter in everyday life. When we wayfind, we act in the environment based on the structure and features of the environment, set against a background of knowledge which is generally understood as having visual characteristics. As mobile and wireless technologies proliferate in urban space it can be considered as having an existence in terms of several spaces, those of places that make up our direct perceptual experience and those of the digital devices and networks that facilitate communication, which are primarily non-visual in nature. This thesis will extend existing work on perception and action in urban space to investigate the role of mobile and ubiquitous technologies in wayfinding and environmental legibility, or more literally how we orientate and find our way in space when we experience it both with and through technology. In order to do this, the research takes the approach of considering wayfinding as a situated activity that takes place against a rich and articulated background of experiences and social connections. Through a series of empirical studies the concept of wayfinding situations is explored from two different perspectives. The first study investigates the relationship between an individual and technology as they act in environmental settings, by comparing learning for a spatial task depending on whether the individual accesses a map or a mobile map to make judgements. The second study seeks to understand the relationship between individual and environment as they act in technological settings, and focuses on the perception and action in space as affected by wireless technologies. The combined outcome of these two empirical studies provides the basis for the definition of a richer and more differentiated concept of wayfinding situations. This informs the final stage of the research in which an applied response is proposed to supporting wayfinding in a specific urban scenario, where the aim is to embed the technology into the spatial setting.

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I dedicate this thesis to Bernd and to Robert.

[1]

Trace of GPS movements during the duration of working on this thesis

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1

Introduction

1.1 Abstract

In this introductory section a brief definition of the term wayfinding is introduced in the sense that is approached and understood in the research. The broad motivation for the thesis is then introduced. The nature of the identified research problem is then described, based on a set of real-world problems. Following from this the broad aim of the research is outlined. Finally an overview of the thesis structure is outlined.

1.2 Definition of Wayfinding

This thesis takes the everyday activity of wayfinding as a problem domain for studying how indviduals interact with technologies in an environmental setting. In order to establish the sense in which the term wayfinding is approached in the research work, the following outlines a simple definition of the term:

The term wayfinding generally encompasses all of the ways in which people and animals orient themselves in physical space and navigate from place to place. However over the last fifty years it has been used more specifically in the context of the built environment to refer to the user experience of orientation and making decisions about how to navigate through the spatial layout of places. The authors Arthur and Passini, in (Arthur and Passini 1992) attribute the term 'way-finding' to the urban planner Kevin Lynch (Lynch 1960), stating that its first occurrence was used in his book, The Image of the City.

Wayfinding i.e. getting from some origin to a destination, is one of the prime everyday problems humans encounter. It is a purposive, directed and motivated activity (Golledge 1999). Humans use different wayfinding strategies depending both on their own individual spatial awareness, and also their knowledge of the environment they are travelling through. However, this focuses on the task at hand and gives no indication of what it is that is actually being done, in order to find one's way. In many cases it is useful to consider the process through which an individual completes a wayfinding task, so as to differentiate the various aspects. A basic approach to the wayfinding process is given by Downs and Stea who define four sub-tasks. The first task is orientation, which refers to the process of determining one's position in an environment, which is followed by the second task of defining the route, i.e. planning one's route to the destination. The third sub-task requires that wayfinder keeps on the right track, in order that they can complete the final task of discovering the destination (Downs & Stea 1977, Daniel & Denis 1998, Richter & Klippel 2002). This process implies not only the act of travelling from origin to destination plus the act of spatial problem solving and encompasses a person's cognition of their environment.

A key aspect of the process of wayfinding of relevance here is the nature of visual perception and the role of mental imagery in creating internal representations of the spatial world. The importance of visual perception is highlighted by the psychologist Gibson where he states that wayfinding is '*purposive locomotion such as homing, migrating, finding one's way (wayfinding), getting from place to place, and being orientated, depends on just the kind of sequential optical information continuous visual perception of the environment described*' (Gibson 1979, p. 76). However Gibson stresses that there is more to wayfinding than purely responding to visual information in the environment, and although cognition and perception are essential to a definition of wayfinding, there are many other factors.

Wayfinding is also fundamentally a learning process, the nature of which not only changes in the development of a child into an adult, but also with personal experience. It is generally agreed that wayfinding knowledge acquisition is in three stages; identification of landmarks, a procedural route knowledge, formed when travelling between two landmarks, and a structural survey knowledge. Siegel and White estbalished in their seminal work 'Image and Environment' that such knowledge permits the direct retrieval of spatial relationships between points without reference to the routes connecting them (Siegel and White 1975). However these stages may not be entirely sequential, and Montello has proposed that aspects of knowledge may develop more as shifts in knowledge that are qualitative in nature (Montello 1998).

The knowledge learnt about a space is not direct acquisition of everything we experience, since our spatial world is simply too large and complex for us to pay attention to and remember everything. This results in a schematisation of knowledge where certain useful information about the environment is selected and structured in a conceptual form in our memory (Freksa 1999, Tversky 2001). As the wayfinder then navigates the environment they refer to these conceptualisations, and it is critical that there is a direct correspondence or relation between the processes of perception, the spatial world and any external representations such as a map (Freksa, 2004).

It is for this reason that it is critical to find ways of bridging the gap between information about the world, spatial information in the world and information in the head. Consequently the particular aspect of wayfinding, which is addressed in this research, is the role of various forms of assistance or external information to guide the wayfinder. In fact wayfinding is rarely undertaken without referencing some form of external information source. This is because we often navigate in semi-familiar or unfamiliar environments where we simply don't have access to existing knowledge to guide us. Thus we rely on cartographic maps, guides and more recently on digital sources of spatial information to provide us with an understanding of the features and configurations of space that we have not been able to build through personal experience.

Wayfinding is much more than a process; it does not take place in a vacuum but is instead immersed in the rich social setting in which the wayfinder thinks and acts. Thus, the final aspect of wayfinding to be considered is that it takes place in a social world; we rely on people as external sources of information and our wayfinding activities are almost never undertaken for the pure purpose of moving physically from A to B. Instead they are motivated, influenced and affected by our interactions in the social world; we travel to and from places to visit people, to get to work and for pleasure.

In this thesis the work is undertaken based on the concept of wayfinding situations; a term which seeks to address the way in which the wayfinding process cannot be seen as a purely isolated cognitive activity, but is instead embedded in a rich and complex spatial and social world. This approach is outlined specifically in the Chapter 3.

1.3 Motivation

The research takes the view that the ubiquity of mobile and wireless technologies has caused a change in the way in which individuals perceive and act in urban space. This is grounded in the underlying premise that space creates a framework for our experience and action in the world. It is for just this reason that getting lost is one of the most stressful everyday events that can happen to us, for our spatial environment provides orientation and structure to our lives. In wayfinding we use the structure and features of the built world to guide us as we move around. A critical characteristic of wayfinding of relevance in this research is the fact that although we experience spaces in many ways, we tend to associate visual characteristics with places. For this reason we find salient or legible elements in the environment easier to remember and they help us to orient ourselves in our daily lives. In addition certain memorable aspects of visual form and structure make it easier to form associations with other aspects of place, and in so doing enable them to weave more smoothly together with the social meanings in space. Thus a dominant landmark in a city becomes an obvious meeting point for friends and so on. The spatial world is not a passive, background to our everyday lives, but rather provides a framework on which we orientate ourselves, both literally and metaphorically.

It is for this reason that the configuration and presence of mobile and communications offer significant issues for the way in which urban space is perceived and constructed. The problem lies in the fact that these features and configurations are not visible in nature, and do not conform to existing concepts of metric or Euclidean space. If we are to support wayfinding in the environment we need to make the technological features and configurations of the urban space legible so that people are able to find their way. However the challenge is; that if these technologies do not operate on a visual level how can they be integrated into our experience of the world so that they can help structure experience and action?

The primary motivation for this research is therefore to understand and propose how we can support wayfinding and perception of urban space when it is experienced through interacting with technology. The thesis seeks to find more appropriate ways to support the interaction between individuals, environments and technology so that people can successfully orientate themselves and find their way in urban space.

1.4 Research Problem

The everyday research problem that motivated this thesis arose from the perceived challenges of interacting with mobile and wireless technologies delivering spatial information in urban environments. In particular the specific characteristics of an individual's interaction with GPS based navigation devices seems to result in people making large wayfinding errors in everyday scenarios. As a consequence of the perceived 'accuracy' of such systems to register and identify a location, mapping problems occur with such devices in terms of the way information is interpreted, such as that described in the newspaper report in The Evening Standard, 22nd March 2007 (see also Fig 1.1) below:-

'The school outing to Hampton Court Palace ought to have been a fairly simple journey. The driver chose to rely exclusively on his satellite navigation system - and 60 children spent the whole day being driven round in circles after it directed him to a narrow street in the north of the capital. A 63-mile journey that should have taken 90 minutes took eight hours. The incident brought a warning from the AA that drivers had begun following satnav directions 'like robots' and needed to have at least some idea of where they were going before setting out.'

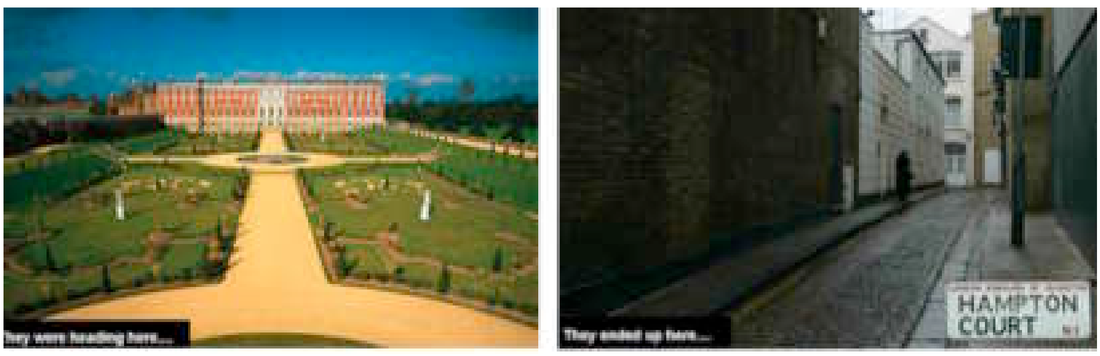

Fig 1.1: The two Hampton Court's (The Evening Standard, 22nd March 2007)

The practical problem described in this report above suggests that sometimes when people use spatial information on mobile devices to assist them in navigating through the city, they can make large, even dangerous errors and they may also not be able to recognize these errors. This is not an isolated incident; there are numerous subjective reports of people making basic navigational errors when using mobile maps; cars driving off cliffs, lorries driving down inaccessible country tracks etc. It has developed to such an extent that in the UK the Department of Transport has resorted to installing 'ignore your satnav' signs (The Daily Mail, 10th February 2007) at recognized danger points. (A collection of newspaper articles covering this topic is included in Appendix B).

It appears that the driver identified in this news article wasn't able to match his knowledge and strategies for navigating the urban environment with that delivered by navigation assistance in a successful manner. It might also be assumed that as a consequence the driver did not actively learn about the environment through which he was travelling, instead becoming merely a passive receiver of information. This may seem an entirely trivial issue; people misinterpreting their satnav systems and getting lost as a result. But when we consider this problem on a broader level it has very significant implications for how people navigate and most importantly learn about their spatial environment, when this interaction is mediated through mobile and wireless technologies. This thesis proposes that people are essentially offloading spatial learning onto such technologies, much in the way that a diary enables offloading of important dates or a mobile phone means it is no longer necessary to remember friends' phone numbers. In many ways this is a useful resource; we can then concentrate on remembering facts or concepts that we prioritise as important for informing future actions. But when we consider our experience of our spatial world, it is in fact vital to be able to remember aspects of the environment one has travelled through or where we have developed a spatial mental model for interpreting an unfamiliar environment. Both mobile devices and wireless technologies embedded in the environment for offering and delivering do not support such learning; as demonstrated by a casual comment by a radio presenter when discussing satnav systems:

'It's possible to drive 200 miles with your satnav turned on and have no memory of where you've been'
(Presenter, BBC Radio 4, October 2007)

In fact engaging an individual in some form of mental effort whilst wayfinding in their environment is a positive process. A seminal study of London taxi drivers by researchers at the Department of Neuroscience, Imperial College London led by Eleanor Maguire and published in 2000, found that the right hippocampus portion of their brains had literally been enlarged as a result of learning 'the Knowledge' or remembering the features and configurations of London Streets (McGuire et al. 2000). The researchers reported that:-

'What marks out cab drivers is the repeated storing of spatial memories from the daily experience of navigation' (The Financial Times, August 25 2007).

A further level of the problem is that the environment is increasingly embedded with the networks that support the delivery of mobile and wireless technologies; WiFi nodes, mobile phone cellular networks, Bluetooth transmitters and GPS navigation systems. In terms of the visual and spatial properties of such systems, they remain not just visually hidden but also occupy non-Euclidean spatial structures as part of the urban environment. This is not just an inherent condition of such technologies, and in many cases a conscious effort is made to conceal and disconnect them from urban structures; thus we wonder at why our WiFi node is suddenly unavailable, why our GPS displays our location as different to where we actually are, mobile phone masts are installed in the city as fake trees (see Fig 1.2), and very few people are aware of either the status or naming of their Bluetooth device (Kindberg & Jones 2007).

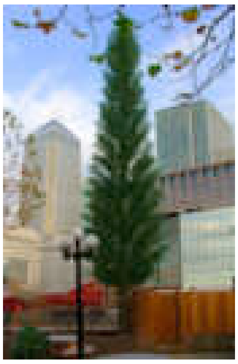

Fig 1.2 Mobile Phone mast in Canary Warf, London (image Francis & Lewis website http://www.fli.co.uk/pTrees.php)

On a broader level this means that the structures and features of such technologies are not meshed into urban space; they operate on almost entirely different paradigms. The models of interaction for how individual's perceive, interact and enact space and technologies are different. This manifests itself in daily interactions; for instance the phenomena of 'kara gattai' identified by the researchers Licoppe in and Inada in their sociological study of the use of a GPS-based game in Japan:

'Without intending it, the designers of Mogi have left open the possibility for players to "freeze" their positions in a given place, by getting there, connecting to the game, and not refreshing their radar screen after they have left the place. Players have been quick to discover and exploit this loop in the game software. They have used it to invent a new form of playful encounter based on the disjunction of their actual embodied location and the apparent onscreen location of their icon that such a "freezing" of the icon's position on the game map allows. The goal is for a player to position his icon at a given place so that later another player will move so that his own icon will appear onscreen close to the first one, or, better still, will touch it. This practice is called 'cara-gattai', cara standing as an

abbreviation for character or icon, and 'gattai' referring to the concept of joining, or rejoining. The practice of doing 'cara-gattai' ostensibly relies on the disjunction between what happens in the screens and in the space of ordinary perception: 'cara-gattai' is meaningful in the way it actually disjoins co-proximity and co-presence, while preserving co-presence a salient feature of the situation, as a potential relevant development that maybe mentioned, discussed and joked upon.'
(Licoppe & Inada 2007 p. 5)

In this example, the individual literally plays with the possibility for occupying a physical space in the city and technological space which are not simultaneous.

These research problems cause fundamental questions to be raised about how an individual relates and acts in their spatial world when they also experience it through technology. If we return to our specific problem domain; that of wayfinding, this thesis proposes that if individuals are to wayfind successfully in our everyday lives we need to develop and utilize strategies for conceiving these spaces and for the corresponding development of spatial learning. If current implementations of mobile and wireless technologies delivering spatial information do not support the spatial learning process in a meaningful manner, people will start to become essentially 'blind' to their spatial environment and will find minor wayfinding tasks a challenge.

1.5 Aim

In order to find ways of interweaving the visuo-spatial characteristics of the spatial world and the features and structure of mobile and wireless technologies into a legible framework the research outlined in this thesis seeks to address the topic of identifying suitable forms of wayfinding guidance or assistance. Instead of proposing that we rebuild or alter the physical world to adapt to mobile and wireless technologies, or that we redesign the fundamental interaction paradigms of mobile and wireless technologies it seeks to investigate how the interaction between these two can be made more fulfilling. Wayfinding is typically supported by many forms of assistance delivered through the representation of spatial information. The interaction between the individual and the spatial world is mediated by referring to abstract representations of space, such as maps, guides and spatial descriptions. These representations essentially seek to create a way for individuals to understand one domain from the viewpoint of another. The final issue tackled by this research is therefore how to create forms of assistance that can represent the two domains of the spatial 'real' world and the space of mobile and wireless technologies so that someone can find their way. This approach creates special challenges since it requires a way of responding to an issue that has been referred to as 'the problem of mapping'. This occurs when information in two different reference systems do not match or correlate, resulting in the person either making an error or being unable to make a decision. In the interaction with technologies, such mismatches have been referred to as '*seams*' (Chalmers et al. 2004), a term which acknowledges the junctures that are created between technology, human and environment. A key aim of this thesis lies in re-evaluating the situational aspects of an individual's relationship with technology in spatial settings, using the problem domain of wayfinding. The importance of being able to study human activities in real-world settings is summarised in the statement by the influential computer scientist Mark Weiser: *'observing the way people* ***really*** *used technology led towards thinking much more about the detailed situational use of the technology, and in particular how computers were embedded within the complex social framework of daily activity, and how they interplay with the rest of our densely woven physical environment (also known as 'the real world)'* (Weiser et al. 1999, p. 693) If wayfinding as an activity is to be supported successfully by technologies then the basis for the interaction has to start being less about the technology, and more about a spatial and social world we act in.

1.6 Outline of Thesis Structure

The thesis continues in Chapter 1 with a definition of wayfinding, together with an outline description of the motivation, research problem and aims of the thesis. Chapter 2 then proceeds to present a review of literature in the field. The review is structured into three sections; individual, environment and technology. This framework is introduced with the intention of identifying and understanding the complexity of the topics raised by the research problem from the perspective of a range of different fields.

Chapter 3 introduces the approach taken by the thesis, which seeks to combine the three domains of individual, environment and technology into a unified method, and defines this concept as 'wayfinding situations'. This provides the context for presenting the primary research questions that guide the three field studies of this thesis. This is then framed by a description of the limitations of the research work. The second half of the chapter presents a review of methods, including the need for an interdisciplinary approach which is discussed and justified. This is followed by a discussion of the methodological approach with a description of how the methods from Architecture, Psychology and HCI[1] have structured and influenced the work in the thesis. The choices of appropriate methods for individual studies, including relevant design and evaluation methods, are given and justified. Finally a more detailed outline of methods used in individual chapters is outlined.

The first stage of the empirical research is presented in Chapter 4. The first study focuses on the nature of the interaction of individual's with technology, and how this is affected by the spatial environment. This chapter responds to the first research question, directed at understanding the nature of spatial knowledge acquisition when it is experienced through interaction with mobile

[1] The field of Human Computer Interaction

devices. The results of this study are presented and discussed, with an explanation of how these findings impact on the wider research problem of interaction with mobile technologies in urban settings.

Chapter 5 presents the second stage of the empirical research which focuses on the individual's interaction with the environment and how perception is affected by the presence of wireless technologies. This chapter responds to the second research question outlined in Chapter 3, directed at evaluating spatial perception in the urban setting. The study takes place in a real-world environmental setting and is structured into three phases. The first phase focuses on perception of localized presence of wireless network (WiFi) technologies, the second phase on the perception of the configurational infrastructures and the final phase develops into an investigation of how these factors influence patterns of behaviour in urban public space. The chapter concludes with a discussion of the wider issues and implications of the empirical findings.

The outcomes of the empirical work in Chapters 4 and 5 is then summarised and integrated in Chapter 6. This chapter reframes and re-evaluates the theoretical approach to wayfinding situations, drawing on the detailed findings from the empirical work. This work provides a basis for the final stage of the research project which seeks to implement the findings into a proposal that responds to the specific problems identified.

The following chapter, Chapter 7, describes the application of the empirical findings in a specific environmental setting. The particular aspects of the setting, together with a real-world scenario provide the basis for the development of a series of studies which identify requirements of a system. The features of a system are then presented, and the process of the development and testing of a working prototype is described.

Chapter 8 provides the discussion and conclusions of this thesis. It draws together current theory and the original empirical work completed in this research by providing a summary of the outcomes from the studies in response to the aim of this thesis. It reviews the research questions and summarises the responses to those questions. It then details the three significant contributions of this thesis that are directly related to each of the research questions. This chapter closes with suggestions for future research directions.

1.7 Conclusion

In this introductory chapter the broad motivation and aims of the thesis, together with an outline of the structure were introduced. This included a definition of the term wayfinding in the sense that it is approached in the research. The broad motivation for the thesis was then introduced, which was followed by a description of the particular real-world research problem addressed in the research. Deriving from this the aim of the work was discussed. The chapter concluded with outline of the thesis structure, with a short explanation of the content and approach of each of the individual chapters.

2

Literature Review and Background

2.1 *Abstract*

This chapter provides a critical review of the research background and current theory as presented in the literature. This literature has informed and inspired this investigation and provides the theoretical foundation for the design of the methods and the development of the empirical studies that form a key part of this thesis.

2.2 *Introduction*

The literature review is structured into three parts; the first looks at individuals, the second reviews the research background on the spatial environment and the final section provides a perspective on technology.

2.3 *Individuals*

The following presents a review of current literature and approaches to the way individuals interact with their spatial environment.

2.3.1 *Individuals: Mental Representations of Space*

Our immediate understanding of space is through perceptual experience, and in attempting to make sense of this direct experience we order and categorize our spatial perception. Through this process we endow space with meaning, whose characteristics are understood as a combination of commonly perceived and highly personalised images. These mental images of space enable us to weave together multiple, fragmented experiences into more coherent and manageable concepts, which then guide our subsequent action and perception in space. The process through which an individual acquires knowledge about the spatial environment is generally referred to as cognitive mapping, a term introduced by Tolman (Tolman 1948). Cognitive mapping is described by Downs and Stea as a process composed of a series of transformations through which an individual '*acquires, codes, recalls and decodes information about relative locations and attributes in a spatial environment*' (Downs & Stea 1973, p. 9). It is a dynamic process and occurs following successive experiences of sequential routes, where knowledge about the environment is integrated into configurational survey representations (Siegel & White 1975). These permit the direct retrieval of spatial relationships between points without reference to the routes connecting them. In more familiar environments a person will utilize a highly configured mental representation which, according to Lynch, is the '*generalized picture of the exterior physical world that is held by an individual*''

(Lynch 1960, p. such stored spatial memories are used to guide spatial activities and tasks (Golledge 1999). Kitchin further underlines the role of cognitive maps '*as a mnemonic and metaphorical devise; a shaper of world and local attitudes and perspectives; and for creating and coping with imaginary worlds'* (Kitchin 1994). Thus cognitive maps are not map-like in the sense that they represent some form of stable image, but are rather an ongoing process where experience and memory of the spatial world is transformed into knowledge in the mind of the individual.

A good deal of the time we proceed in wayfinding tasks based on piecemeal spatial information in unfamiliar or semi-familiar environments where we do not have access to learned configurational structures. For example when we approach a new city for the first time and arrive at the central station, we will attempt to formulate a travel plan based on our experience of all the other cities and the various possible positions of the central station. We will make assumptions about the structure and features of the city, and as we move through the city we encounter situations that either confirms or rejects our suppositions. These spatial elements do not necessarily need to have strong visible features or shape, as one might expect a typical landmark to be. Instead it is the way in which they work in conjunction with the organisation of the space, and thus they degree to which they are perceived as salient or legible by the individual as they move through the environment. Such cognitive strategies are based on our previous experience of similar environments; a form of conceptualised background knowledge (Portugali 1996, Raubal et al. 1997) or image schemata (Johnson 1987, Neisser 1976, Thorndyke & Hayes-Roth 1982), which by means of imagination are used to help us relate to the world and categorize it. These schemata are the recurrent mental patterns that help people structure space. Configurational schemata are supported by cues (Couclelis et al. 1995, Golledge 1999) or salient features of the environment, which provide structure within a mental model and help to organise it through their relational properties.

In a large-scale environment the structure and features are '*revealed by integrating local observations over time, rather than being perceived from one vantage point'* (Kuipers 1982, p. 203). Since knowledge is acquired over time this can result in them being fragmented, incomplete, or distorted (Golledge 1999, Tversky 1981). During navigation several reference frames are possible, primarily based on the viewer, object or environment. Directions and axes are not represented analogically or metrically but more categorically. This results in a schematization of such spatial knowledge into elements and paths relative to reference frames that allow integration of fragments into a whole. Although schematization allows integration of disparate bits of information, Tversky highlights the fact it also introduces error (Tversky 2003). This may account for the occurrence of unpredictable processes which Downs & Stea refer to as '*augmentation*'; where individuals add nonexistent features to their mental representations (Downs & Stea 1973 p. 21), perhaps to ensure a more comfortable fit with the individual's expectation of how they imagine it should be structured. Although schemas help to support memory by reducing the retention of spatial information considered unnecessary they can also result in error when features in the environment do not correspond with stored representations. Thus, although we exploit features and structure of the environment in learning, the mis-matches between the characteristics of the real world and that stored in our memory is a consequence of an imperfect mental process of trying to make sense of what we have perceived.

The opportunities the environment offers for supporting such mental models are also intertwined with the way an individual perceives the world when they undertake task-based activities[2]. A key feature of such activities is that perception and memory processes occur simultaneously. For example, during wayfinding task an individual may be travelling from one place to another, whilst concurrently involved in other task, such as having a conversation with a friend who they have met on the way, or stopping to buy something in a shop. These activities do not detract from the core wayfinding task, but they make demands on the attention of the wayfinder. During such tasks the situation always provide more information than can possibly be processed. Peripheral, as well as central, information is always present, peripheral in a physical sense, since the area behind oneself is no less a part of the environment than that in front, and peripheral in the sense of being outside of the focus of attention. Thus wayfinding is not an isolated mental process, since the individual is an integral part of the system they perceive, to the extent that the strategies chosen become part of the perceived environmental setting.

2.3.2 Individuals: The Role of Environmental Structure in Knowledge Acquisition

Our perception of the world is one of a flow of continuity, but it is supported by successions of space, motion, orientation and meaning which seem to be part of the connected whole. Generally we manage to react to and organize this flow of environmental information so that we can act in the world. Yet we do not simply passively process a response to a complex world, since we have also learnt to utilize characteristics and structure of space to guide us in the way we act. In fact as far as Greek times, we have used the legible properties of the environment to help us to structure the process of learning information. The Greeks used a method called the spatial mnemonic, which exploits the structure of space to enhance human memory. In this method the first step is to memorise a series of loci or places. Images from a speech or other written work which are to be remembered are then placed in the imagination in the places. As the orator makes a speech he or she imagines moving through the space in their imagination, drawing from the memorised places the images where they were placed in sequence (Yates, 1996 p 18). Once saved to memory, the position of the loci may be used again and again for a whole range of material. The mnemonic illustrates not just the power of spatial relations to support knowledge, but also the

[2] Task-based activities (as opposed to scenario based) take place in a context of a set of tasks that are directly linked to the goals they serve, such as using a map to find one's way from A to B.

essentially visual nature of the way in which space is experienced. Although we experience spaces through many senses, we tend to associate visual characteristics with places. For this reason we find salient or legible elements in the environment easier to remember and to orient ourselves in our daily lives. In this way certain types of predominantly visual form and structure are more easily identified and acted upon.

Typically individuals observe the environment whilst moving through it. These patterns of motion are called paths, and environmental elements are perceived as arranged and related along these paths (Lynch 1960). For many people these are the predominant elements in their mental representations of space. The behavioural pattern or movement performed by moving along a path is called a route (Klippel 2003). When moving along a path an individual experiences an organised sequence in which phases follow each other meaningfully in an order (Siegel & White 1975). The critical aspect of this experience is that it is perceived whilst in motion. In fact observers are aware of, even in remembering the dynamic quality of a path, the sense of motion along it. Objects or landmarks along the path can define it more clearly, or heighten the effect of motion. Route following in wayfinding also involves recognizing an origin and a destination and identifying districts and sequences of features that make up the route.

The experience of the environment as an individual moves along a path or route also has a sense of spatial sequence. The continuity and rhythm are similar to music or film. But the critical aspect is that vision is the principle sense. The attention of the observer is caught by both near and far objects, such as signs, traffic, the sky, topography and buildings (Downs & Stea 1974). These form landmarks along the route, by becoming part of the sequential experience of the observer. The observer locates these moving objects and space in a total structure, orientating themselves with regard to the world around them.

But why have paths emerged as such a vital organisational structure for our experience of the external environment? The world experienced in motion is constantly changing, and since human attention span is severely limited in its intake of information some means of recoding perceptual intake is necessary. Thus we have developed skills to recognize the structural properties of sequences and events, their recurrence and regularity (Carr 1969). We learn to strip events of their redundant features and to perceive 'event structures', that is to locate the predictive underlying simple structure that can be recognized or unified over time. 'Event structures' or paths are simply a way of categorising the flow of the present into manageable chunks, which can then be transformed into memorable events.

The way an environment is learned as a spatial sequence has a consequential effect on the nature of the knowledge acquired. For instance studies (Golledge et al. 1995, Peponis et al. 2004) have found that subjects who undertook a wayfinding task within a very simple regular environment performed showed significantly worse performance when they took one route when this was compared to performance for another route, even where the routes on plan were very similar. Thus the difference in the way the environment was experienced as a certain sequence of events and features significantly affected the degree of error with which the individual completed the task. A contributing factor may also be '*orientation specificity'* (Montello et al. 2004, p. 263), since direct experience of an environment is related to the subjective viewpoint of the individual as they move through it. For example we have all experienced the characteristic of a route or path, which when walked in one direction is familiar and legible, but often completely unrecognisable when walked in the opposite direction. The difference in the direction or sequential experience of the environment, and therefore its configuration, affects comprehension.

2.3.3 Individuals: Maps and External Environmental Representations

Individuals supplement their knowledge about spaces with external sources of information, such as maps, written descriptions and various forms of external environmental representations. A map is a third source of information about the environment, besides the individual's mental representation and the environment itself. Maps both record what is known and remembered about an environment and act as wayfinding aids (Golledge 1999). From a map, people acquire survey knowledge encoding global spatial relations. This knowledge resides in memory in images that can be scanned and measured like a physical map (Thorndyke & Hayes-Roth 1982).

In a study by Thorndyke and Hayes-Roth study (Thorndyke & Hayes-Roth 1982) which compared spatial knowledge acquisition for participants who had learned an environmental setting (a floor of a building) using a map and those who had learned it form direct experience, the researchers found differences in learning. The navigation participants (with several months of experience in the building) had better orientation abilities and performed particularly well in route distance estimations, whereas both navigation and map participants made good estimations of direct distances between two points (Euclidian distance). According to Thorndyke and Hayes-Roth, map-based training compensated for the hard-earned experience of the navigation group only for estimates that were directly based on survey knowledge. Map learners acquire a bird's eye view of the environment that encodes survey knowledge sufficient to support performance on a variety of estimation tasks (Thorndyke & Hayes-Roth 1982). When using knowledge to perform spatial judgments individuals have direct access to the knowledge required to estimate distances and judge object locations. But in the use of maps, individuals access indirect sources of spatial information. It is cognitively difficult to rotate the map frame of reference to the eye level perspective in order to make decisions in the environment. This is because it is thought that memory for space is defined with respect to intrinsic frames of reference (e.g. Mou &

McNamara 2002, Shelton & McNamara, 2004), which are selected on the basis of egocentric experience and environmental cues. Consequently problems can arise when the individual has to transform or rotate the map representation to match direct experience of the environment, since this implies mental or physical effort [Levine et al, 1982, Thorndyke & Hayes-Roth 1982]. This results in a difference between learning that takes place from eye level perspective and learning that takes place by examining configurations and layouts, such as when using maps.

Memory for spaces can therefore be differentiated depending on whether it has come from direct or indirect sources. Direct sources are navigational experience of a space through walking or standing, whereas indirect sources include maps and other navigational aids which offer external representations of the environment to which they refer. Montello and Freundschuh outlined eight differences between the way information sources vary in the manner they present information, which include scale, ease of reference, perspective, level of abstraction, level of detail, whether the information is static or dynamic, the degree of schematization and the level of precision (Montello & Freundschuh 1995).

Wayfinders are familiar with using paper cartographic maps to navigate and make decisions. However more recently map-like information has become available in a variety of digital formats. For instance, the use of online applications such as Google Maps to plan a trip has become an alternative to consulting a road atlas before embarking on a trip. There has also been a corresponding increase in the use of GPS navigation systems for many everyday wayfinding tasks (we refer to such systems as mobile maps). Mobile maps present map-like information but on a mobile device, and with the user's position presented as an overlay dot or trace on the map display. In addition mobile maps often have an additional level of interaction, where a user can specify a particular wayfinding task by entering a destination and start point, and can then be guided to a destination through a series of spoken or visual route directions. Mobile maps can also present problems due to issues with the map perspective, such as those described above, although some forms of mobile navigation aids present information from an egocentric viewpoint in order to assist individuals matching the direct and indirect sources. However a key difference with mobile maps is that they offer dynamic visualisation of the map information, generally derived from GPS data, have zoomable interfaces and are generally fairly small in view area which means that factors such as scale, ease of reference and level of detail will result in differences in knowledge acquisition.

2.4 The Environment

This section reviews the scientific background and current state of the art regarding the effect on an individual's perception of urban space when it is experienced through and with mobile and wireless technology. It sets this in a context of the concept of image-ability or legibility.

2.4.1 The Environment: Image-ability and Invisibility

We identify with space, and particularly built space, as having visual appearance and physical form, whether this exists in the perceptual present or cognitively as a representation. Lynch defined the importance of clarity in the features and structure of such mental conceptions of space and stated that '*an ordered environment can do more than this; it may serve as a broad frame of reference, an organizer of activity or belief or knowledge... Like any good framework, such a structure gives the individual a possibility of choice and a starting-point for the acquisition of further information'* (Lynch 1960, p. 6). He further proposed that an important characteristic of built space is that it should be image-able or legible. Lynch defined image-ability as a '*quality in a physical object which gives it a high probability of evoking a strong image in any given observer*' (Lynch, 1960, p. 9). It incorporates configurations of landmarks, routes, regions, and '*includes comprehension of distances and directions, linkage, connectivity and scale'* (Golledge 1999 p. 21). The underlying assumption is that the city image is dependent on the image-ability of the configuration of urban elements, which pre-supposes visual experience and memory for space.

The emergence of communication technologies has affected the nature of visual presence and perception of space. Communications networks tend to be largely invisible and silent, or at most relatively hard to discern. The result is that there is a general tendency for people to ignore or even deny the effects of the invisible environments of media, simply because they are invisible. Consequently a number of authors have highlighted how the predominant visuo-spatial way of understanding of the city is being fundamentally affected by such technologies which have very little visual presence, and enable us to be anywhere and everywhere. Graham draws attention to the fact that '*most weave unseen through the fabric of urban spaces, using very little space'* (Graham & Marvin 1996, p. 50). Batty further noted that '*cities are becoming invisible to us in certain important ways'* (Batty 1990, p. 128), and in another paper he set out a research agenda which looked at a series of methods for enabling a visualisation of these nodes and networks (Batty & Miller 2000). This has also been addressed by Dodge and Kitchin (Dodge & Kitchin 2000) in their work on describing the features of what they term 'cyberspace'. Similarly Townsend (Townsend 2000) and others have highlighted how the temporal quality of wireless and mobile networks reconfigure the spatial and visual qualities of the city, and so should cause us to question the nature of city infrastructures and how we plan out cities and physical and social sites of activity. The question then arises as how we perceive the spaces of mobile and wireless technologies in the city, if we can neither see, hear, or touch them, nor model their structure on existing bounded spatial concepts. It would seem that the layering of digital and physical space enables us to experience some sort of intertwining of experience, which is subsequently conceptualized. As with the process of mentally mapping urban space, corresponding images of the abstract topologies of communications networks and electronic spaces '*need to have emotional and subjective information about the qualities of the electronic places found as well as basic information designating what is where within the complex and interlocked web of logical spaces*' (Graham & Marvin 1996, p. 122). However it seems that the frameworks of mobile and wireless technologies are being mapped too carelessly onto the spatial structures of the city, in part because the dilemma exists of how to give such media spatial and visual form. The lack of coherent visual or spatial identity indicates that such nodal points and networks problematises the creation of meaningful internal or mental representations. Yet wireless communication technologies are becoming extremely dense in urban settings; each square metre of the city is increasingly populated by mobile and wireless technologies, so that their presence cannot be denied in the built spatial world. But the manner in which the city is traditionally perceived in visual terms has implications for the image of the city, as this has by its own definition an inherently visual form. If these technologies, however dense, are not perceived in visual or spatial terms then they will not enter in the consciousness as an aspect of the image-ability of the city. This means that cities are becoming invisible to us on certain levels, and thus our strategies for orientating and finding our way in urban space need to be re-considered.

The immateriality of communications networks is not just a superficial outcome of the technology infrastructure; it is fundamentally intrinsic to the nature of data transmission in such networks. This is in part because such information transfer is achieved through what are termed packet networks. When information is transmitted in a communications network a process occurs where the original data is divided up into uniformly sized parcels of bits, called packets. In preparing data to be sent in the network, each packet is labelled with a header stating from which message it was drawn, its position in the message and its destination. Each individual packet is then sent through any communications route that has capacity, so that the original data is literally totally dispersed in the network, and '*only realized as a whole again when it is reassembled upon reaching its destination*' (de Sola Pool 1990, p. 33). At each end of the network connection a node provides the sites of arrival and departure for the data, where temporary data may also be further processed or recorded onto memory. Consequently, one can consider the nature of information flow as enabled only through its own fragmentation, such that it is not possible to conceive of the information as sustaining any materiality during transmission. Whilst in transit the content and form of information is thus everywhere and nowhere, in fact it can only be tangibly realized at the node. In wireless networks the data is not even confined to a cable linking two nodes, but is instead literally transmitted through the air at wavelengths that are close to the speed of light.

The technologies that enable us to remain connected, even when we are not literally plugged in, are the networks and nodes of mobile and wireless communication. These enable transfer of information between separated points without physical connection. This access is most often not the type of access we refer to in physical settings, such as using a key to open a closed door. It is instead connectivity with networked infrastructures of information. As such, current technology still requires information to be served from somewhere and delivered to somewhere; at geographic scales a 'bit' of information always has an associated location in real geographic space. Consequently Hepworth highlights the fact that these technologies also '*consist of physical systems made up of links and nodes that are constructed fundamentally of spatial systems linking together only certain places highly unevenly* (Hepworth et al. 1987, p. 800). The nodes and networks of mobile and wireless technologies may be invisible and placeless, but the technologies that enable and access them are located in social and physical spaces; where people are, what they're doing and whom they're communicating with. Thus the spaces through which we move become visible in terms of their network accessibility, and consequently, in terms of their implied spatial locality.

The abstract material characteristics of communications technologies mean that it is both conceptually and practically complex to form adequate perceptual parallels with existing concrete and imaginable concepts of space. Mobile and wireless technologies have specialised infrastructures, and as these technologies emerge in the city, they become overlaid with existing urban configurations. The individual's image of the city, which they use to navigate and orientate themselves within urban space, is no longer confined to physical elements and configurations. The Lynchian concepts of landmark, node, path, region and edge (Lynch 1960) can be re-mapped onto digital infrastructures, supporting new interaction in the city. Below is an outline of the various mobile and wireless technologies, their particular technical properties and how these can be considered in terms of their relation to spatial settings and structures:

2.4.1.1 WiFi

The proliferation of wireless Internet or WiFi nodes in urban environments is creating a dense communications infrastructure, which re-draws existing spatial thresholds and territories. The nodes, which are essentially black box transmitters operating on the frequency of the 802.11b standard create a region of access of between forty-five metres indoors and ninety metres outdoors. Due to the extent of the region, or territory, access to the node can be available well beyond the physical borders and thresholds that traditionally delineate spatial boundaries. The information flow largely ignores the material thresholds of walls and doors and extends beyond traditional materially bounded notions of space.

2.4.1.2 Bluetooth

Bluetooth, which is a short-range radio technology, operates in a manner similar to nodal networks but differs distinctly from WiFi nodes in that it is closely associated with the enabling device which is usually mobile. Offering a typical range of ten metres (approx. thirty three feet) the node creates localized access. Bluetooth does not have a visual presence but is instead perceptible within the device interface, which despite being mobile has a consistently identifiable presence regardless of its actual location.

2.4.1.3 Mobile Phones

Mobile phone technology operates on a cell infrastructure called a network. Individual hand-held devices can receive a signal anywhere within the network. As an individual moves around in space the network infrastructure monitors when they approach the boundary of a cell and transfers their call to the next cell. Mobile phone networks are provided by a series of transmitters, typically located on masts or on the top of tall buildings. These remain largely invisible in everyday life, and thus the infrastructure of mobile phone technology is rarely considered, aside from when an individual moves into an area where there is no 'network availability'.

2.4.1.4 GPS

In some cases the mapping of spatial characteristics onto communications technologies creates issues, because the two frameworks function on different paradigms. Despite the fact that the infrastructure operates to deliver spatial information, the technological framework of GPS itself is spatially abstract. An individual attempting to identify their location with a GPS receiver and remaining in the same physical position could be presented with a series of different positional co-ordinates whilst actually remaining stationary. Similarly 'shadows' from large physical objects effectively cloud the accuracy and boundaries of the information space. The signal transmission is interrupted by material structures such as tall buildings, creating in effect information shadows overlaid on physical space. However, due to the distant motion of the satellites this accuracy is variable over time, such that in the period of a few seconds GPS accuracy can change from a few metres to fifty. GPS does not create a structure in the manner of a network, but instead exists as a global Hertzian space which can in effect be tuned by those receiving the signal. The space of GPS is not materially bounded or inhabited, but temporally fluid, and operates beyond physically conceivable limits. As such, the manner in which the infrastructure exists at both a human scale, in terms of the receiver, and concurrently at a spatial scale of tens of thousands of miles makes it particularly difficult to map onto existing spatial structures.

The key outcome of a closer review of the characteristics of mobile and wireless technologies is that they cannot be imagined or visualized in the visual terms in which we understand the world around us. Quite simply these technologies do not occupy space in the same sense that we have come to perceive metric urban space. Thus it is important to find ways of conceiving the presence of mobile and wireless technologies so that people can use this knowledge to find their way in spatial environments. It may be problematic to make the features and configurations of such technologies image-able in the sense that Lynch originally intended the term, but it is possible to consider a way of making them legible, in the sense that they can be clearly understood and acted upon.

2.4.2 Environment: Mediated Space

Mobile and wireless technologies create numerous opportunities for communicating in multiple and varied locations without the requirement for a wired connection. As a result, Meyrowitz points out that '*where one is has less and less to do with what one knows and experiences'* (Meyrowitz 1986, p. viii). But communication technologies are intimately related to the spatial world, in that they enable communication at a distance and as such free communication from a fixed location in space. On the one hand such communications technologies, which whilst crucial in supporting the mobility and flux, are also fixed networks that must be embedded in space. The media theorist Castells has popularized this space as the 'space of flows' a concept where space is understood as linking up electronically separate locations in an interactive network that connects activities and people in distinct geographical contexts (Castells 1996). He contrasts this with the concept of the 'space of places' which he defines as organizing experiences and activity around the confines of locality. The complexity of the urban condition arises when '*the emerging space of flows is folded into the space of place's* (Castells 2004, p. 86).

In common with the proliferation of communications technologies, increased physical mobility has had a similar transformative effect on perception and behaviour in spatial settings. In fact, the two conditions are fundamentally linked, since before electronic telecommunications, when all communication necessitated physical movement, action over distance was only possible through physical movement (Graham & Marvin 1996). Movement from situation to situation involved movement from place to place. However, according to the theorist Virilio, information input and output has replaced modes of transit usually associated with the movement of people or objects traditionally distributed in space (Virilio 1997). The view of space as some sort of container, which bounds perception and action, no longer provides an adequate description for the spatial manifestation of media technologies. Instead, a more complex framework is necessary, where multiple spaces and times become overlaid within the framework of a single experience such that places are no longer defined by their physical boundaries.

2.4.3 *The Environment: Techno-social Situations*

In considering the effects of technologies on urban space it is critical to include the social settings in which an individual acts, since these frame experience of such spaces. Up until now much of the research in this field has considered the environmental setting in Euclidean spatial terms as a three-dimensional structure, where qualities such as location can be defined in terms of exact metric co-ordinates. This is also reflected in the work of those concerned with the characteristics of space in terms of its physical features and configurations, such as Lynch (Lynch 1960). These qualities of space afford essentially physical constraints, based on the fact that humans cannot walk through walls, that objects do not float, and that light creates shadows on surfaces. However, alongside this domain of spatial settings is a world of social settings, which take their sense from configurations of social actions. The sociologist Goffman introduced the concept of settings; based on the concept that social interactions and activities are dependent on settings or situations which are '*guided by the physical qualities of the setting*' (Goffman 1969, p. 20). Thus the physical properties of space also provide social affordances, based on socially acceptable norms such as the fact that we have different types of conversation on street corners than in bedrooms, and we would feel comfortable shouting at a football match, but not in a church. Space frames human action and interaction in multiple and varied ways.

Structural characteristics in the environment play a more fundamental role than mere formal perception, so that physical forms are assigned certain significance in the manner which they create possibilities for certain types of behaviour. However people also manage to adapt their behaviour to take into account the presence of such technologies. As such spatial behaviour is both informed by the possibilities of the physical space and those of the technologies available in the space. Since the primary role of such mobile and wireless technologies is as a medium of communication or interaction, they exist within social as well as physical settings. But little is understood about how the social spaces of the technologies correspond with or diverge from the spatial structures within the environment.

In everyday life it is difficult to distinguish the particular aspects of the frameworks which affect behaviour; they overlap and interweave in sometimes indistinguishable ways. Space as a concept must be understood as a multiple layered setting in which an individual perceives, acts and interacts. Thus a place such as railway station may not just act as a place to catch a train, but as a space for waiting, for reading, for loitering, for watching, for meeting and more. Critically, these multiple activities are not mutually exclusive; and so, for example, the individual act of waiting does not detract from the ability of the station to host the arrival and departure of trains. The social situations that occur in these overlapping behaviour settings support gatherings that possess a special characteristic in that they exist on more than one social level. In this sense space is incredibly flexible in allowing multiple activities to occur simultaneously without affecting its integrity. However the twin potentials of mobility and communication have undermined the traditional relationship between physical setting and social situation. Walls, doors, gates, and distances still frame and isolate encounters, but communications media increasingly trespass on the situations that take place in physically defined settings. Meyrowitz highlights the fact that these media re-organize the social settings in which people interact, weakening the once strong relationship between physical place and social place (Meyrowitz 1986). Physical presence is no longer a significant factor in the experiences of people and events, since it is both a possibility and a routine to communicate directly with others without meeting in the same physical place. Consequently, the physical frameworks that once created distinct spatial settings for interaction have been greatly diminished in social significance.

Interestingly many of the relationships which structure our social world are not analogous, but operate on network type structures consisting of strong and weak ties, which are relational in nature. This means they do not exist as entities in themselves, but only exist in context of the link to other entities in the network. In many ways these social networks have much closer structural form to the way in which we understand communication technologies than the space in which they take place. If we think about a building in Euclidean terms, it is an enclosed space with a particular function. But if we look at it in terms of its social structure it can be seen as a complex series of loosely and strongly connected links and nodes making up a social network (Adams 1998), which even have the possibility for total disconnection from all other nodes. For instance a place such as a church or a classroom is physically designed and socially designated to support a radial topology of communication, with uni-directional links from one person to many, whereas a cafe topology consists of clusters of bi-directionally connected nodes (the tables) which are loosely associated to form a large network (the cafe), with optional one-way (eavesdropping) links The social use of a space is similarly temporarily fluid. A church may appear to visually be a church building with fixed walls, but for the people that visit, it may be a place to pray privately, a place to congregate with a group, or a place to mourn on a one-off occasion, or a place of celebration for a wedding or baptism. All these ways of occupying the space are valid, and they do not conflict. This implies that despite the relatively rigid notions of Euclidean space by which we perceive a church building we are far more flexible in accepting the church as a place of many simultaneous and often diverse social settings.

Yet, presence in space as mediated by new technologies has a different type of aesthetic, no longer dominated by visual access but by informational access. The features and structure of the interaction is enabled by a connection, which is not necessarily achieved through physical movement from one location to another. As such, everyday actions and behaviours no longer belong to particular places, and are now multiplexed and overlaid; there now exists the possibility to switch rapidly from one activity to another while remaining in the same place, so we end up using the same place in many different ways. This concept is defined by Ito as *'"technosocial situations"* which act *'as the frame for practices that hybridize technological, social, and place-based infrastructures'* (Ito & Okabe 2005, p. 12). The consequence of communications technologies in urban settings is that multiple social realities can occur in one place. The same physical space may be caught within the domain of two different social occasions.

Mediated encounters are no longer confined to face-to-face interactions in set times. Meyrowitz, states that the consequence of communication technologies for social interaction is that it is '*no longer the physical setting itself that determines the nature of the interaction, but the patterns of social information flow'* (Meyrowitz 1986, p. 36-37). The information spaces of these technologies enable a disassociation to occur between the setting and social behaviour. They overcome the limitations set by such physical boundaries and situations, and in so doing they not only offer more effective or comprehensive access to environments and behaviours but also they provide new opportunities.

2.5 Technology

The final overview of literature relevant to this research covers the role mobile and wireless technologies plays in affecting the interaction of individuals with their environment. It focuses in particular on technologies that support wayfinding activities.

2.5.1 Technology: Situating Computing

Mobile and wireless technologies such as WiFi[3], GPS[4], RFID[5], 3G Mobile[6], and Bluetooth[7] running on a whole range of handheld and wireless devices enable communication whilst on the move and without a fixed connection. These are also referred to as ubiquitous computing (Weiser 1991), pervasive computing (e.g. Hansmann 2003), context-aware computing (Dey & Abowd 1999), location-based services (e.g. Raper et al. 2007) and in the context of the city the term urban computing has been introduced (e.g. Shklovski & Chang 2006, Kindberg et al. 2007). These developments can be traced back to the emergence of the field of ubiquitous computing at Xerox Parc in the late eighties. At this time a key change in thinking arose out of observing how

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[3] Wireless Fidelity. Wi-Fi is a wireless technology intended to enable the interoperability of wireless local area network products. A Wi-Fi enabled device can connect to the Internet when within range of a wireless node.

[4] Global Positioning System. GPS is a constellation of satellites that enable GPS receivers to determine their current location, and are used in navigation systems.

[5] Radio Frequency Identification. RFID is an automatic identification method, relying on storing and remotely retrieving data using devices called RFID tags.

[6] Third Generation Mobile Phones. 3G is a mobile phone standard which enables network operators to offer users a wider range of advanced services.

[7] Bluetooth is a wireless protocol utilizing short-range communications technology facilitating data transmission over short distances from fixed and mobile devices.

people really used the technology, which approached the growing field of ubiquitous computing from the standpoint that technologies should '*weave themselves into the fabric of everyday life until they are indistinguishable from it*' (Weiser 1991 p. 94). This took a different path from the PC (personal computer) paradigm, of one person one computer located in a particular setting, and suggested a new direction in the study of individual's interaction with technology. It responded to the ability of mobile and wireless computing applications to adapt to a user's information needs without taking too much of their attention, whilst taking advantage of the dynamic environmental characteristics such as the user's location, people nearby, time of day and even light and noise levels (Chen & Kotz 2000). Consequently, the surrounding environment has started to be brought into a much more detailed consideration, for example by directly observing the phenomena and people (e.g. Oulasvirta et al. 2003, Paay 2003, Cheverst 1998).

An aspect of the 'real world' that has been the subject of study is that of the role of social practices, which challenges the paradigm of the person interacting with the computer, and instead sees the person as inhabiting an information space. This follows the concept of the computer 'reaching out', in which interaction moves from being directly focused on the physical machine to incorporating more and more of the user's world and the social setting in which the user is embedded (Dourish 2004). In particular, the concept of 'social navigation', which was introduced by Dourish and Chalmers in 1994 and later became the topic of an edited book by Hook and colleagues, attempts to describe the practice of exploiting social practices to help users navigate and explore system functionality (Dourish & Chalmers 1994, Hook et al. 2003). Social activities and interactions provide a resource, which may be recorded and presented to others through wireless devices, and serve in social navigation. This concept provides a useful approach for exploring how aspects of the everyday social setting of the individual can be identified and given priority in the interaction with technology.

2.5.2 Technology: Re-Placing Space

A critical characteristic of mobile and wireless technologies is that they have enabled communications technologies to escape from the traditional physical confines of built space, since they can be both embedded and mobile. Yet, in a review by Chen and Kotz of context-aware computing applications they found that '*few contexts other than location have been used in actual applications'* (Chen & Kotz 2000 p 6). In fact, location is often considered an index from which to infer the overall context influencing the mobile application (Dix et al. 2000). Consequently the multi-faceted attributes of the 'real world', or the surrounding social and physical environment, are often under-represented in the research. Environmental attributes, whether this is a location or other characteristic of the physical space, are often not considered a dynamic part of the interaction itself, as this is seen as occuring primarily between the user and the technology. Therefore the surrounding environment has not been regarded as a mutable information source with which people are interacting. As a response to this, Harrison and Dourish highlight the role of space and place in the interaction with technology in their paper which is titled 're-placing space' (Harrison & Dourish 1996). This work signalled a move away from considering the properties of space in more abstract terms. Harrison and Dourish offer a way forward by proposing that '*in everyday action, this appropriate behavioural framing comes not from a sense of space, but from a sense of place'* (Harrison & Dourish 1996). They underline the fact that place, (by which they mean the social and behavioural aspects) rather than space, is the notion that provides a suitable framework for understanding people's interaction with their physical environment. They define a range of characteristics of space which can be exploited as part of a spatial model for interaction; '*relational orientation and reciprocity, proximity and action, and finally partitioning and presence and awareness*' (Harrison & Dourish 1996 p. 68). They proceed to describe the emergence of mediated space which they refer to as '*hybrid space'* (Harrison & Dourish 1996 p. 72). The approach outlined in this paper provides a useful route to thinking about the issues and challenges associated with the consideration of spatial settings and the interaction with technology.

In re-assessing technologies implicit relationship with space a number of other researchers and theorists have also proposed ways forward. A key work is that of McCullough (McCullough 2004) who introduced a way of thinking about the merging of physical and computing spaces which he terms 'digital ground'. Other theoretical approaches, such as those discussed by Mitchell (e.g. Mitchell 1993) and Greenfield (Greenfield 2006) have discussed similar issues. From a HCI perspective there is an increasing body of research which seeks to investigate and understand the way individual's interaction is both influenced by, and influences, the use of spatial settings. Paay and Kjeldskov's work on defining indexicality in everyday situations makes a useful contribution of starting to understand the implications of situated interactions and the consequent possibilities for design (Pay and Kjeldskov 2008). In a similar vein the work of Brown and Laurier adopts ethnographic methods to investigate the settings in which people interact. In Brown and colleagues study of the use of a public square, a system is proposed which allows individual's to share their experiences with others both far and near, through tablet computers that enable the exchange of photographs, voice and location (Brown et al. 2005). A separate study by Brown and Laurier observed individuals' studying maps in an everyday situation and commented that map reading '*is irretrievably immersed in the organization of specific social settings, be they workplaces, holidays, competitive sports or military reconnaissance'* (Brown & Laurier 2005, p. .22). Fatah gen. Scheick and Kostakis studied the way individuals explored the installation of an interactive 'carpet' in an urban setting (Fatah gen. Scheick & Kostakis 2007). A final approach has been in the design and subsequent study of applications that respond dynamically to the situation in which they are employed. This is most prevalent in the introduction of tourist guides and other 'location-based' technologies, such as gaming applications which explore interactions in spatial settings. For instance Geelhaar and colleagues describe the implementation of a location-based guide in a Museum environment (Geelhaar et al. 2004), and Cheverst and colleagues review some of the issues associated with a context-aware tour guide (Cheverst et al. 1998). However guidance and wayfinding applications tend to have been developed from the starting point of supporting the interaction between individual and device, with features and structure of the situation being incorporated as the individual moves and acts in the world. In the context of wayfinding activities there remains the challenge of finding ways of situating the interaction in the physical setting so that it is an intrinsic and interwoven characteristic of the situation of the interaction rather than a source of information.

2.5.3 Technology: Mobile Wayfinding Assistance

Mobile and wireless technologies create new possibilities for where, when and with whom to interact. However they also offer new interaction paradigms in the interface between individual and the technology. In order to understand the potentials of such technology it is therefore useful to consider the concept of affordances. The psychologist J.J. Gibson stated that '*an affordance of an environment is what it offers, what it provides or furnishes, for good or ill. It can also be considered as a combination of physical properties of the environment that are uniquely suited to a given individual*' (Gibson 1979, p 127). In this way the affordance of the technology is not just what it offers in terms of features of capabilities, but more in terms of a kind of a rich community of practice, which is generated out of a wider understanding of its use. In this sense the affordances of technology can be understood not as their potential to deliver instruction or even create environments for knowledge acquisition and learning, but instead as environments or tools that enable users to construct their own models.

In the context of wayfinding this way of thinking about interaction with technologies is important because it provides a way of approaching tasks that are underspecified and changeful. For instance a person who sets out on a trip from A to B may decide mid-task to also visit C. They will also quite possibly be involved in other secondary activities during the wayfinding task. When we are on the move in an environment we need to keep track and attend to many different forms of often unrelated but concurrent tasks; the route we are taking, a mobile phone call, the traffic in the road and what we plan to do later on in the evening. Indeed, while mobile, we almost always have numerous unfinished, simultaneous, successive, and overlapping tasks. As well as processing this information and managing it, we also make decision about what particular aspects to commit to memory so that it may be used in the future. There is a constant balance to evaluate what needs to be retained and what can be discarded. However error is involved when our attention is divided between concurrent tasks. For example a study by Lindberg and Gaerling found that when participants were engaged in a secondary task whilst navigating a route were less able to keep track of where the learned locations were, than a groups when they were not engaged in a parallel task (Lindberg & Gaerling 1981). Oulasvirta has highlighted the specific demands of such multi-tasking in relation to the use of mobile devices (Oulasvirta 2005) where users need to cognitively manage the fragmentation of attention experienced 'in the wild'.

On a task level, mobile map type navigation applications seem to provide an ideal solution to the problem of getting local information on where to go whilst in the process of completing a wayfinding task. However there are issues with demands on attention, since the user is required to attend to information delivered incrementally during the task rather than acting on a stable plan developed before starting on the task itself. These situations may arise due to the nature of human cognitive processing, and is a consequence of the fact that during tasks that involve some direct relation with the environment, cognition can be considered to be situated. The individual exploits the environment to reduce the mental workload due to limits on their information-processing abilities (e.g. limits on attention and working memory). In this manner the activities that occur during the development of spatial knowledge cannot be considered as solely residing in the head of the individual, but instead is distributed across the individual and the situation as they interact. The mobile device effectively acts as an external store of spatial knowledge.

Consequently, wayfinding provides a particular challenge since it is necessary to support an individual's mental processes through offering a model that can represent the features and structure of the environment in a way that it is not separate and abstract, but part of the situation in which the interaction occurs. The interaction with a mobile map is often based on a paradigm where the map tries to replicate information about the environment to reduce mental effort. Hutchin's also highlights this issue, and states that navigators often make mistakes because they imagine that the reality presented to them by the information matches the reality in the physical and social world (Hutchins, 1995). The question is how to represent the different domains so that the interaction between them both acknowledges their differences but also creates a way of understanding them on common terms. Mobile wayfinding assistance needs to positively respond to the apparent mis-matches between the world of external spatial information and that of the rich and differentiated aspects of physical and social settings. In doing so it may be possible to find and develop ways of assisting individuals as they think, move and act in order that they may be able to literally find their way in the world.

2.6 Key Gaps in the Literature

Individuals

The theoretical work in the field shows little reference to possible applied solutions in responding to the identified mismatch between the form of information in abstract spatial representations such as maps and individuals internal spatial mental models.

Environment

There is a lack of empirical work on how individuals perceive the features and configurations of environments embedded with mobile and wireless technologies, particularly with reference to their proposed lack of visual form.

Technology

Current interaction paradigms implemented into wayfinding applications need to find ways of responding and incorporating spatial settings together with individual cognitive abilities into a more situated interaction.

Combined

There is a missing level of research combining the theoretical and applied work from the different fields into an interdisciplinary approach that can respond to the spatial, social and individual aspects of perception and action in urban space embedded with mobile and wireless technologies.

2.7 Conclusion

The second chapter of this thesis reviewed a wide and interdisciplinary range of literature and was structured into three sections; individuals, environment and technology. In the review of the literature with regard to individuals the nature of spatial knowledge acquisition as a cognitive task was discussed. The nature and role of internal representations was discussed, particularly with respect to the interaction with external representations such as maps and other forms of information about the spatial environment. The features and structure of spatial knowledge were then reviewed from the perspective of how the environment itself creates a framework for perception and action in space. This was extended into the domain of how technological features and configurations are overlaid onto the spatial world, with a focus on how this creates mediated spaces. The lack of coherent visual or spatial identity for these techno-social spaces was highlighted and the subsequent problem identified in the creation of meaningful internal or mental representations. Finally the review covered technology and outlined a focus on mobile and wireless technologies which were identified as being particularly relevant to perception and action in urban settings. This included a focus on the role of technologies in providing wayfinding assistance, and how the cognitive abilities of individuals are not necessarily well supported by current models of interaction in such applications. The chapter concluded with a summary of the key gaps identified in the literature.

3

Research Questions and Methodology

3.1 Abstract and Introduction:

In this chapter the primary research questions and methodology are described. Initially, an outline of the fundamental approach adopted by the research work is described to clarify the intention with which the work is framed around the concept of 'wayfinding situations'. This is followed by the primary research questions, which are also derived from the critical review of literature in Chapter 2. To frame the scope of the research some limitations of the study are presented. The chapter concludes with an introduction to the methodological approach to the entire thesis, with particular attention drawn to a justification and description of the interdisciplinary nature of the research methods. This is followed by a more detailed outline of the methods of investigation used and their associated research instruments.

3.2 Approach: Wayfinding Situations

'The foundation of actions by this account is not plans, but local interactions in our environment, more and less informed by reference to abstract representations of situations and actions, and more and less available to representations themselves... the function of abstract representations is not to serve as specifications for the local interactions, but rather to orientate or position us in a way that will allow us, through local interactions, to exploit some contingencies of our environment, and avoid others'
(Suchman 1987 p.188)

This thesis takes the standpoint that rather than seeing individuals, the environment and technology as separate entities, the way we interact with the world means that our actions are 'situated'. In this manner, wayfinding is not an activity that can be studied by focusing on one aspect, but must be seen in a holistic manner as a process undergoing change affected by a whole range of dynamic aspects. In its approach it draws on the concept of 'situated actions', a concept developed in 1980's by Lucy Suchman which attempts to find a way of understanding and responding to the relationship of humans with technology in real-world situations. In her presentation of the concept of 'situated actions', human communication, instead of being structured by a set of pre-defined plans but rather that '*every course of action depends in essential ways on its material and social circumstances'* (Suchman 2007, p. 70). Suchman uses the example of navigation to illustrate the concept. Referring to a study of Polynesian navigators undertaken in the sixties by Gladwin (Gladwin 1967), Suchman describes how these navigators do not embark on a trip with a pre-defined plan, but instead act on background knowledge to make contingent decisions as situations occur at sea. This is in stark contrast to the model of western navigation which relies on a model of planning based around abstract and fixed representations of space and thus independent of the exigencies of the particular situation. The situations of the actions of the Polynesian navigators are never fully anticipated, and are continuously changing around them; a condition which is in fact directly comparable to the type of everyday wayfinding decisions we all take in moving through space.

The concept of situated-ness has been explored by many researchers and theorists, and despite many similarities in ideas of what characterises situated-ness, these approaches also expose different perspectives. These viewpoints originate from an extraordinarily broad range of fields; Sociology (Goffman 1969, Meyrowitz 1986), HCI (Dey & Abowd 1999, Dourish 2001), Anthropology or Ethnography (Suchman 1987), Cognitive Psychology (Hutchins 1995, Wilson 2002), Architecture (McCullough 2005) and Geography (Batty & Miller 2000, Massey 2007). Despite varying perspectives, one common concept that seems to persevere is that context is a relational property (Dourish 2004), which means that the various aspects of a situation cannot be seen as isolated, but are fundamentally interrelated. The urban planner Kevin Lynch underlined this as follows *'nothing is experienced by itself, but always in relation to its surroundings, the sequence of events leading up to it, the memory of past experiences',* (Lynch 1960, pg. 1)

One of the most common questions that faces us in day-to-day life is 'what shall I do now?', and this reflects the fact that humans constantly face the task of orienting future action, although this is mostly acted through some form of ready-made definition (Carr 1948). In this context the domain of wayfinding is approached as a problem-solving spatial activity that is constantly undergoing change. In wayfinding knowledge continues to remain under construction with each new situation, experience and activity, and we continuously process information in an effort to contextualise it. Consequently the situation of the action can be defined as the full range of resources that the actor has available to convey the significance of his or her own actions, and interpret the actions of others, which implies a '*mutual intelligibility'* (Suchman 1987 p. 6). But in order to develop such shared understanding there must be clear awareness developed through a learning process, and often based on some form of common language. This is paradoxically set against the practical fact that design of interfaces risks inadvertently destroying many of the most valuable aspects of current ways of doing things because we do not understand the way they work (Hollan et al. 2000). If we intend to facilitate knowledge construction by modifying the use of technology, they must be aware that the mind will continue to construct a mental image that includes the surrounding environment. In searching for shared intelligibility between human and computers, a way needs to be found to more sensitively represent and respond to situated interactions.

This approach requires that the topic of wayfinding not simply be seen as a problem-solving act occurring sequentially within the mind of an individual, but as a changeful and rich process. This process is highly interdependent on many, often unpredictable, factors in the real-world setting as well as background knowledge. The real-world setting, in the sense in which it is referred to in the research, extends to include the highly important context of the social setting in which the individual acts and makes choices and also an individual's interaction with external sources of information. To study wayfinding in this manner necessitates a holistic approach, and also one based in empirical study in real-world settings, in order to fully understand the range of factors affecting the situation in which a wayfinder perceives and acts. This research seeks to adopt such an approach in order to investigate wayfinding situations as they actually take place, rather than as an abstract set of processes, and in particular it aims to assess how an individual's relationship with technology affects the nature of the situation. The research problem this thesis therefore seeks to address is therefore summarised in a point form below.

3.3 Primary Research Questions

The research questions addressed in this thesis develop through three levels of study:

- Investigation: What is the nature of individual's spatial knowledge acquisition when space is experienced through mobile and wireless technologies?

- Evaluation: How is the experience of urban space changed as a result of the effect of mobile and wireless technologies on perception and learning, and how can we enable these technologies to respond to the situational aspect of the interaction?

- Implementation: How can we find better ways of enabling the situated interaction between individual, device and urban space so that wayfinding in the environment is supported?

3.4 Key concepts and Assumptions

- Wayfinding is a dynamic activity that is an everyday task; as such it provides a vital test bed for understanding how we act and interact with ubiquitous technologies in spatial contexts.

- The environment in which we move and act is complex and rich, yet many mobile and wireless technologies are often based on providing forms of information that do not reflect how an individual acts and reacts in wayfinding situations.

- Mobile and wireless technologies should support spatial learning, by complementing the cognitive abilities of the individual and the salient features of the environment as understood as situations.

3.5 Limitations of the Study

This thesis approaches a large subject with an inter-disciplinary approach, and as such it is limited on two levels which may on the surface seem contradictory. Firstly, in terms of the empirical research it must exclude some aspects of the problem and focus on specific aspects in order to undertake meaningful fieldwork. We define these conditions as follows:-

- Environment: The study focuses on urban public space. It excludes private space and enclosed space.

- Technology: The study focuses on mobile and wireless technologies as interactive devices used for providing and delivering spatial information. It excludes other task-based interactions (refer to definition in section 2.3.1).

- Humans: The study focuses on individuals, in particular aspects of how they perceive, interact and enact wayfinding situations. It excludes the nature of the interplay of groups and larger social structures.

Conversely due to the breadth of the subject matter it seeks to adopt a holistic approach where the inter-relatedness of the various domains (individuals, technologies and the environment) is considered not in isolation but as a whole. As such the scope of the study is in many ways extremely broad in nature, and the relationship between the various stages of the study may not be immediately clear to a reader more familiar with work originating in a very clearly confined problem domain.

On a methodological level, due to a focus on real-world conditions and interdisciplinary study, the methodologies chosen can sometimes be less rigid and detailed than those used in traditional pure scientific data collection and analysis. (i.e. it was necessary to sacrifice scientific exactness for a chance to understand the problem and analyse it). This is discussed in detail in the following section.

3.6 Methodology

This thesis purposely takes an interdisciplinary approach, as demanded by the subject matter. In its methodological structure it seeks to respond to the identified research problem by opening up a series of questions and to seek, through a series of empirical studies, to explore suitable answers rather than proving or disproving a pre-defined hypothesis. The methods adopted produce both qualitative and quantitative results, which in most cases are considered to possess equal merit. As an outcome, it responds to an analysis of empirical findings with a proposal for implementation within a real-world scenario.

3.6.1 Introduction to Interdisciplinary Approach

In order to adopt interdisciplinary working methods, one of the basic building blocks is to engage in an exchange of knowledge between two fields. This is set in the context of scientific specialisation which has created boundaries that to some extent prevent or hinder open exchange, and focuses instead on production and delivery of knowledge. As a consequence the very specialisation obtained in a long process of professional training and the identity formation connected with it can be problematic. The process of exchange is not merely a matter of initiating communication; it is a question of communicative competence. Establishing the framework and terms of the interaction is often the most challenging stage of the process. This is because traditional disciplinary training serves to create a community or audience of people who can understand what is said, with the outcome that members of the community tend to only read the literature in their particular research speciality. However such structures make it extremely difficult to exchange, generate and integrate knowledge across disciplinary boundaries. It is often the cases that developing a common language and introducing colleagues from other disciplines to one's own perspective are described as the key problems of interdisciplinary co-operation. This is because one's own assumptions on which the conversation is based are designated as one's own perspective and that of the other person as perspective of the other (Bromme 2000). Every act of communication presumes a common cognitive frame of reference between the partners of interaction called the common ground. The common ground theory assumes that any verbal encounter represents an act of co-operation '*two people's common ground is, in effect, the sum of their mutual, common, or joint knowledge, beliefs and suppositions*' (Clark 1992, p. 93) but, problems of perspective provide some of the greatest hindrances to creating a common ground of interaction. In interdisciplinary communication, differences in common ground are frequently 'discovered' only when the partners of co-operation find out that they use the same concepts with different meanings, or they use different codings for approximately the same concepts (Bromme 2000).

In this sense, interdisciplinary requires an ability to creatively engage in knowledge negotiation. This is set in the context of scientific specialisation which has created boundaries that to some extent prevent or hinder open exchange, and focuses instead on production and delivery of knowledge. In this thesis the author has instead taken the approach that the process of such exchange should be considered as '*mutual learning*' (Klein 2001, p. 118). This approach does not only require a simple openness to communication. Instead it demands a fundamental shift from producing knowledge and then presenting it within a disciplinary audience, to one of knowledge exchange as the primary product. In this sense '*mutual learning is not merely a metaphor, it is a cornerstone of theory and practice*' (Klein 2001, p.228). As such it asks of individuals and organisations to accept that the quality of the scientific research is measured not so much as the success of the product, but rather as the success of the process. This is very much the case with this thesis, which although offering tangible and hopefully scientifically valuable results also provides a contribution in terms of suggesting an approach to research problems that many have identified but where there has been less success in being able to study the subject from a holistic viewpoint.

3.6.2 Why an Interdisciplinary Approach?

This thesis seeks to address the interaction between humans, the environment and technology within a specific context: that of wayfinding or spatial orientation. As such it sees spatial experience as the foundation for the study. The study of perception, action and interaction in space is a research theme approached from a number of disciplines; Architecture, Psychology (Spatial Cognition), Sociology, Ethnography and HCI to name but a few. The thesis starts, not with a research problem grounded in specific closed domain, but with a series of questions, both theoretical and empirical, and a desire to gain deeper understanding of the nature of these problems, with the hope of being able to offer some solutions for creating a response.

Methods in Architecture

Architecture is by its very nature interdisciplinary in nature; it sees humans, their environment and their social setting as inextricably inter-related. Architecture also has the benefit of a discipline framed around not just creating abstract solutions to scientific problems, but of responding in a creative manner to real-world issues. This process is deemed by many architects as one grounded in a creative approach; to some extent it relies not on developing a superior response to existing knowledge in the field or quantitative analysis but on an individual or group coming up with what could be considered an 'intuitive' solution. In many cases this essentially unverifiable process produces good results; buildings don't generally fall down, they provide pleasant settings in their local environment and they provide a support for social and cultural life. Architects generally work within a methodological process where they respond to a 'brief' or problem developed by a third party. In this scenario the third party provides vital information about the requirements of a problem and the Architect develops a response. The weak link in the process is that the Architect is often not required to investigate the problem from the outset, outside of a very specifically defined domain. As such an Architect will approach each research problem with background knowledge, but will generally seek to develop a unique and entirely qualitative response. Consequently there is a deficiency in the field of suitable empirical methods for objectively investigating and evaluating individual's interaction in their environments. Some empirical methodological approaches have been developed that have validity and can be applied across a broad range of problems and can be used to deliver quantitative results. These include Space Syntax (Bill Hillier and Julienne Hanson at UCL, London – methods from Computer Science e.g. Hillier & Hanson 1989), Pattern Language (Christopher Alexander – methods from Sociology e.g. Alexander 1977), Environmental Legibility (Kevin Lynch - methods from Psychology e.g. Lynch 1967). Additionally technical methods from the fields of surveying and engineering provide quantitative information in the architectural process. However, in the research problem identified in this thesis none of these methods provides a suitably robust methodology for investigation. However the basic process through which an architect creates a subjective response to an identified problem involving humans, environment and technology is one which is followed throughout this thesis.

Methods in HCI

Human–Computer Interaction (HCI) is the study of interaction between people (often referred to as users) and computers. It is often regarded as the intersection of computer science, behavioural sciences, design and several other fields of study. Interaction between users and computers is considered as occuring at the user interface. As a discipline, HCI adopts methodology concerned with the design, evaluation and implementation of interactive computing systems for human use and with the study of major phenomena surrounding them. In this sense HCI is very different to Architecture in terms of methodology; it has a set of extremely rigorous rule-based frameworks for empirically investigating how humans interact with technology and the world around them. However the focus of such empirical work tends to be on evaluating interaction with systems which have been developed as solutions to identified problems. Often the 'real world' social or environmental context of the individual was overlooked or no suitable methods were available to evaluate them. Over the last decade ethnographic and psychological methodologies have started to be introduced to the field, which have enabled more authentic analysis. Yet in many ways the field still grapples with how to understand what Suchman terms the 'situated' interaction between individuals with technology and their environment (Suchman 1987) affected by social, physical and psychological factors.

Methods in Psychology (Spatial Cognition)

Psychologists attempt to explain the mind and brain in the context of real life. Psychologists study such phenomena as perception, cognition, emotion, personality, behaviour, and interpersonal relationships. Psychological methods are rigorously embedded in the discipline, and tend to focus on conducting empirical research to investigate and discuss a clearly defined hypothesis. By its nature, Cognitive Psychology focuses on processes grounded in human cognitive abilities and strategies. However it lacks an outlet to propose ways in which these empirical findings can be implemented to respond to and solve real-world problems. As such, it is invaluable as a methodology to gain a greater understanding of an identified problem, both from a social and cognitive level, but requires a further level of interpretation in order to reframe this knowledge into a useful form.

3.6.3 Implementation of Interdisciplinary Approach

As a basis this thesis draws on the foundation of the author's personal background and training in the field of Architecture. As discussed above methodologically the approach is to first define the brief of requirements, then to undertake an analysis of the conditions in which the requirements are based. The next step is to draw up a set of concepts which are tested and finally make a proposal for implementation of the outcomes as a form of solution to the brief. This thesis follows this broad method of investigation and proposal of solutions to the identified research problems. Yet, in the individual sections of the thesis methods from other disciplines have been utilised in order to gain clear empirical understanding of the issues being investigated. This is primarily a considered response to the research problems identified, where a single methodological approach fails to address the broad issues under scrutiny. The study of spatial perception, and the consequential impact of perceptual changes in individual's actions in the world are themes which do not lend themselves to an investigation from one aspect only. None of these can be said to fit neatly into an established scientific discipline. An individual's perception, action and interaction in space is affected by psychological, social and physical environmental factors, none of which can be seen wholly in isolation. Instead an interdisciplinary approach is a response to the inherent integrated nature of a person's experience of their environment, and also how this is mediated by technological factors. In seeking to address the research problem the thesis therefore draws from a number of methodological fields for both theoretical and empirical research. Consequently the author has drawn on the fields of Psychology and Ethnography. In the initial stages, the field of spatial cognition provided a theoretical framework for defining the research questions and outline of the research work. For the analysis stage of the problem, a psychological approach was taken in order to enable a deeper understanding of how individuals actually acquire knowledge. The following testing stage will take a more qualitative ethnographical approach so that the rich qualities of socio-spatial settings can be interpreted in order to further provide constraints for developing an implementation of a proposal. However, in terms of the validity of the methodology, it is important to acknowledge the limitations as well as the benefits of the chosen approach. These are described below:-

Benefits and Drawbacks

In comparison to a traditional work of scientific research this has both benefits and drawbacks. The benefits are described as above; an opportunity to address the holistic nature of an individual's experience and actions in the world. An interdisciplinary approach enables the thesis to study the research problem from a number of angles and see the inter-relationship between the findings. This provides an invaluable platform upon which to develop a response and propose solutions to the research problem.

The drawbacks arise on a number of levels. The first and most obvious is that the author has proceeded on aspects of empirical research in which she does not have specific training or grounding in either the theoretical or methodological approaches. In order to ensure that inexperience or lack of understanding does not prohibit the progress of the work the author has drawn heavily on the support and input of respected colleagues from the various disciplines from which methodologies have been used. In particular collaboration with colleagues from the field of Psychology, Spatial Cognition and HCI have provided a considerable level of guidance, specifically in the empirical fieldwork. To these ends the author has approached this fieldwork with a strong idea of the problem to be investigated, a clear outline of the group, materials and environmental setting for the study and an understanding of how the research outcome may inform the thesis in it's entirety. Colleagues from their various disciplines, most notable cognitive psychologists have then advised on suitable methods and procedures for undertaking and analysing the empirical research. The author has also acknowledged areas where her expertise cannot simply be extended to deal with the level of analysis required. In particular the study in Chapter 4 has a results sections where the statistical analysis of the data was not completed or undertaken by the author herself. In this study she has worked in close collaboration with colleagues, whose expertise in such methods have enabled a comprehensive analysis of gathered data, which the author has then sought to interpret and discuss. However this has involved a clear acknowledgement of the boundaries of knowledge and where others may have expertise that cannot be acquired or simulated without specific training.

A further strategy adopted was to draw heavily on well-respected published work in the various fields, to study their methods in detail and to design research based on extending such work within a particular problem domain, rather than seeking to approach the problem afresh. For instance, a key piece of empirical fieldwork in Chapter 4 takes the approach of extending and re-interpreting a seminal piece of research from the eighties (Thorndyke and Hayes-Roth 1982). This approach was also successfully taken by Ruddle and colleagues, in a similar extension of the Thorndyke and Hayes-Roth study, who tested for knowledge acquisition with an equivalent set of participants, but with a virtual environment setting instead of a real-world setting (Ruddle et al. 1999). By drawing on the methods and results of an existing study the aim was twofold; firstly to enable a direct comparison with the results in the original study (in particular to compare the original navigation participants' results with the mobile map participants in the new study) and secondly so that the empirical work described in this thesis has a recognisable grounding and resonance in a respected research study from the field of Psychology.

A further aspect of interdisciplinary working is that drawing together outcomes arising from different disciplinary perspectives requires a re-framing of the different contributions. The process of re-interpreting the results into a common referential language is a complex one and may create a situation where the results take on a different meaning, or in the worst-case have a questionable contribution once viewed in a different context. The author has also attempted to address this problem by specifically including a chapter following the discussion of the empirical research which seeks to draw the fieldwork together into a common context. Yet, the re-framing of results into a common language will inevitably lead to misunderstandings and misinterpretations, which to some extent are unavoidable in the context of a scientific world grounded in specialisations. This requires a degree of flexibility, from a disciplinary standpoint, to be taken when evaluating the overall merit of the methodological approach.

3.7 Methodology: Detailed Description

3.7.1 Method for Empirical Study One

The first empirical study draws on methods from Cognitive Psychology. The empirical work is structured around a seminal study, published in the journal 'Cognitive Psychology' (Thorndyke & Hayes-Roth 1982), which investigated the differences in spatial knowledge acquisition between maps and navigation. The study starts with proposing a theoretical model as a basis for understanding how individuals interact with their environment and technology. Out of this model a specific set of hypotheses is developed which propose the nature of cognitive processes that occur when individuals make spatial judgements. To test this hypothesis a study was taken in a real-world environmental setting with twenty-four participants. The participants were divided into two groups; one to test for spatial knowledge for the environment when it was learned with a map (a paper map), and the other when it was learned with a mobile map (a mobile device displaying a map). Both groups first completed a learning phase where they were required to learn the spatial information until they could adequately recall it. They then were asked to undertake a testing process, where they were required to make a series of orientation and distance estimates in the environmental setting. The data from the participant's was analysed using a number of statistical methods. The accuracy of orientation and distance estimates was compared between the two groups and also for specific combinations of destinations. Further analysis of participant's spatial judgements was completed through Root Mean Square Error[8] (RMSE) analysis which sought to reconstruct participant's orientation estimates into a form of cognitive map. These results were tested for accuracy and consistency within inter-group differences and also for differences between sets of destinations, to assess the role of the structure of the environment on performance. The results are discussed in terms of how they relate to the original study, and at length in terms of how the participant's perception of the environment is affected by the form of spatial information they learnt, thus drawing on the interaction model introduced at the beginning of the study. The outcomes of the study are further interpreted with particular respect to the role of mobile maps in terms of the learning process between the individual and technology, and the discussion concludes with a series of detailed proposals for improving this model of interaction.

3.7.2 Method for Empirical Study Two

The second empirical study also draws on methods from psychology but in a broader implementation, and with support from sociological methods. In this study the environmental setting is a roughly one kilometre square area in an urban setting in Deptford, South London, UK with a specific user group of individuals accessing public wireless internet. In order to identify the way the environment, and thus physical location is related to the usage of WiFi nodes a series of methodologies have been used. All phases of the study take place in real-world conditions, and seek to understand the corresponding everyday conditions in a specific environmental setting. The first phase of the study involved participants who were included since they were users of a specific wireless network in South East London. However all participants took part in the study voluntarily, and the study took place in the setting and not in a controlled environment. The second two phases of the study involved the gathering and analysis of captured data. Initially, data was gathered in a fixed spatial area and then processed using a series of mapping techniques to establish the actual location and density of the pattern of wireless nodes and their relation to urban public space. Finally, a series of datasets giving details of the usage of the wireless nodes over a specific time period was related back to the location of urban public space through mapping techniques, and the corresponding user behaviour within the space.

3.7.3 Method for Evaluation

In order to understand the separate outcomes of the two empirical studies a chapter has been included which seeks to integrate the two sets of findings into both a theoretical framework and also a basis for the implementation phase of the thesis. This stage of the thesis reflects on the

[8] In statistics, the root mean squared error or RMSE of an estimator is one of many ways to quantify the amount by which an estimator differs from the true value of the quantity being estimated.

research problem domain identified in this chapter and also considers how the empirical findings enable a more detailed understanding of the interaction between individual's, their environment and technologies. In particular it reframes and refines the definition of wayfinding situations which underpins the thesis. This refining of the original research domain is undertaken in order to provide a clear basis for a series of proposals in the final chapter which seek to create a response to the problems identified. A series of concrete proposals are made which define the characteristics of a technological solution to the initial research problem identified.

3.7.4 Method for Implementation

In the final stage of the research a design proposal is described and implemented to prototype stage as a response to the outcomes of both the theoretical and empirical research described in the earlier chapters. The methodology for this stage is based in the field of HCI. The study takes one particular real-world setting; the central area of the city of Weimar, Germany, in order to make a site-specific proposal. The study starts with an outline of a particular wayfinding scenario, which provides the basis for a detailed requirements study. The first requirements study draws on the method of part of study completed by the sociologist Stanley Milgram (Milgram & Joedelt 1976) which was used to assess people's mental idea of the relationship between places in an urban context. The second requirement's study is an observational study, which seeks to understand how the particular features and structure of the urban environment affect the wayfinding practices of those navigating through it. From this work a conceptual design proposal is outlined, which responds to both the particular issues of the chosen urban setting and also the detailed research issues identified in earlier chapters. The final stage is the development of a working prototype, which is evaluated through usability testing. The implementation proposal is then discussed in the context of the program of future work which would further the development of the research. In essence this chapter provides an indication of a practical design solution implemented in a real-world urban setting as a way of responding to the research problem.

3.8 Conclusion

This chapter outlined the approach, research questions and methodology of the thesis. The chapter began by clarifying and defining the concept of wayfinding situations, which provides the approach for the thesis. To create a context for the work to follow, the key assumptions together with an outline of the limitations of the research was then specified. The final section described in detail the methodological approach of the research work, and provided a justification for the interdisciplinary nature of the work. The methodology used for each stage of the research project was then described in detail. Overall, the chapter gave an overview of the structure and scope of the work to follow, and established the basis of the methodological approach.

4

Empirical Study One
Differences in Spatial Knowledge Acquisition between Maps and Mobile Maps in Urban Environments

4.1 Abstract

This chapter describes an empirical study where the effect of different modes of information provision on spatial knowledge acquisition in a large-scale environmental setting was investigated by comparing two groups of participants. The first group comprised participants who had learned the environment from a map and the second group was made up of those who had learned it using a mobile map. The experiment was conducted in an external urban environment and consisted of two phases; an initial learning phase, and a testing phase where participants were asked to provide orientation, Euclidean and route distance estimates. The results show that there are differences between the spatial knowledge acquired between the two groups, and that mobile map users performed worse than map users, particularly on Euclidean (straight-line) and route distance estimation. We propose reasons for the variation in performance as deriving from differences in cognitive schematic frameworks used for learning, and also requirements on attention during the task. We conclude by discussing the implications for learning with mobile navigation applications in urban environments.

4.2 Introduction

The first empirical study described in this chapter focuses on 'mobile' technologies, and studies how the interaction with them is affected by the environment and the strategies of the individual. It is set in the task-based activity of wayfinding, and investigates how mobile wayfinding assistance affects the acquisition of knowledge about space.

4.2.1 State of the Art in Empirical Studies

We use spatial assistance of many kinds to augment the knowledge in our heads, these include maps and also more recently developed mobile maps of navigation assistance supported by GPS (we refer to these as mobile maps (see Meng et al. 2008). Mobile maps seem to provide an ideal solution to the problem of getting local information on where to go whilst completing a wayfinding task. This information is incremental since it is delivered in stages, rather than a paper map source which provides all the information in a stable format and is most useful in the planning stage of a task. However a number of recent empirical studies have shown that individuals who use such navigation applications with mobile maps have poor spatial knowledge acquisition (e.g. Aslan et al. 2006, Krüger et al. 2004, Münzer et al. 2006, Ishikawa et al. 2008).

Münzer et al. compared map and mobile map users knowledge acquisition in a real environment (a zoo) and found that map users acquired better survey knowledge as well as better route knowledge, compared to the knowledge acquired by navigation assistance users. Krüger et al. undertook an earlier study in the same setting and found a significant increase in route memory accuracy for the map-based wayfinding condition compared to the conditions using technology-based navigation assistance. They concluded that mobile pedestrian navigation systems have the potential to convey landmark knowledge but fail to convey survey knowledge. Ishikawa et al.'s study compared map, mobile map and navigation in an external urban setting for participants who walked routes where they were required to find their way to a specified goal. The results showed that participants who had used the GPS navigation system performed worse than either map or direct experience participants. It is therefore critical to undertake further studies which can adequately evaluate spatial knowledge acquisition with such applications. Raper et al. also identified the evaluation of wayfinding interfaces as an 'urgent' research issue in their evaluation of LBS (Raper et al. 2007). However this presents difficulties, as highlighted by Kjeldskov who undertook a comparative study of evaluation techniques and found that '*mobile guides take many of the well known methodological challenges of evaluating the usability of mobile computers systems to an extreme*' (Kjeldskov et al. 2005, p. 62). In order to evaluate knowledge acquisition it is ideal to undertake empirical studies in real-world settings, but this creates issues with both the capture and assessment of performance. In this study we sought to evaluate participants' spatial knowledge acquisition in a large-scale real environmental setting which replicated critical features of the seminal study by Thorndyke & Hayes-Roth (Thorndyke & Hayes-Roth 1982). In the Thorndyke & Hayes-Roth study (hereafter abbreviated to T&HR) knowledge from navigation and maps was compared. The study presents results where we instead compare participants who had learned the environment from a map and those who had learned it using a map on a mobile device (a 'mobile map') while navigating through the actual environment, thus varying and extending the original comparison of maps and pure navigational experience. The experiment also differed from the original study in that it took place in an external environmental setting, rather than a building. However the structure, layout, location of features and scale of the setting was directly comparable to that of the original T&HR study.

4.3 An Interaction Model for Mobile Wayfinding Assistance

For the following empirical work we focus on problem Domain 1 (see Fig 4.1), which focuses on the interaction between the individual and technology, with the role of the environment being studied in terms of how it affects the interaction itself. In wayfinding situations the potentialities of the use of the technology are to a much greater extent in flux, and the task is something that is worked out repeatedly as the situation changes. The technology needs to be able to recognise this sort of re-purposing, and to support the communication of changing conditions to the user. In addition, as these changes occur in the environment, individuals' requirements for information can vary according to their different spatial abilities and backgrounds. Therefore, there is a need for an interaction model to represent these dynamic and relational aspects. Individuals can access and acquire spatial information through a mobile device whilst acting and moving within the environment; and they can also gain information directly from the environment. Individuals have been shown to have differences in terms of spatial ability, acquired knowledge and their social and cultural backgrounds (Hegarty & Waller 2006). Mobile devices, as the technological element, act as information sources and can provide location-related information to individuals. The environmental element can be viewed as including physical, socio-economic and cultural aspects (Golledge & Stimson 1997). The environment in which individuals act also identifies both spatial extent and context in terms of the various situations encountered.

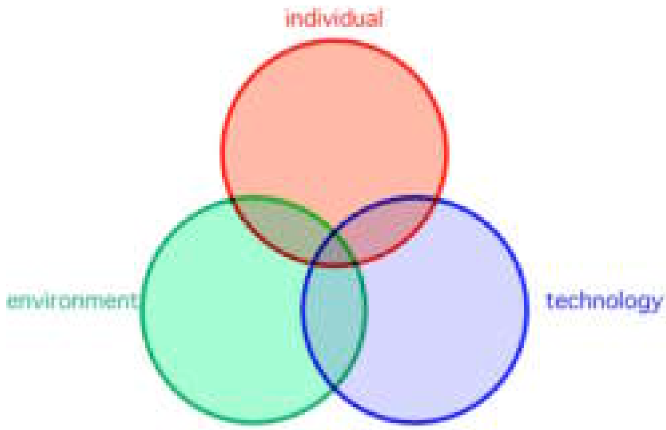


Fig 4.1. Problem domain 1

The model in Fig 4.1 follows that of Freksa and colleagues (Freksa et al. 2007, p. 5) who developed a representation-theoretic notion of spatial context for cognitive agents that interact with spatial environments. Their model displays the three sources of information about the spatial environment: the environment, the mental representation of the agent, and the external representation in form of a map. In the model above, the three sources are similar, although in this case the focus of the study is on sources of spatial information equivalent to a map but delivered through technology.

In order to study the interactions between environments, individuals and devices in wayfinding tasks, we have identified three key relational aspects of the interaction (see Fig 4.2): location, interface and representation.

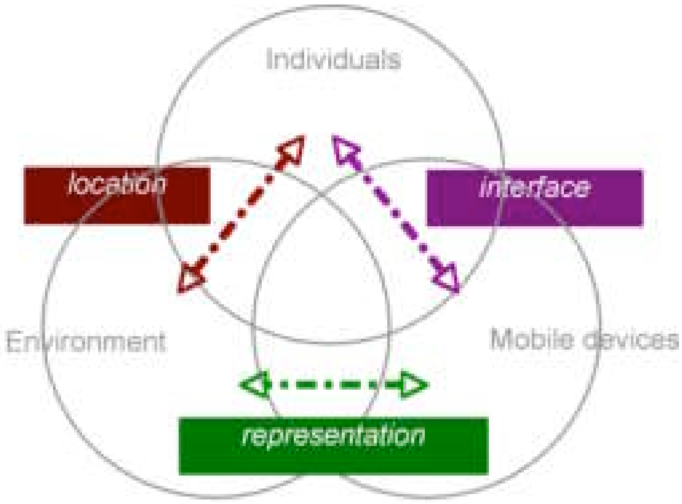


Fig 4.2. A conceptual model of the relation between individuals, technology and the environment

The first aspect, 'location', is to model the relation between environments and individuals. The term 'location' is in a broad meaning of location-related situations, and not limited to the concept of (x, y) position. The second aspect in the model is the relation between individuals and devices, which are denoted as 'interface', which refers to whether an individual is able to cognitively manage the tasks in which they are assisted by the mobile device. The third aspect, 'representation' describes the degree to which the mapping of the worlds is successfully addressed so that the individual understands, and can act upon, the spatial information presented to them. It is important to note that these three aspects of the model should be considered in their totality in the interaction, although they have to be defined individually.

4.4 Experiment Design

4.4.1 Setting

An environment was found that was relatively easy to learn and yet complex enough to make the tasks of orientation, location and distance estimation somewhat difficult. The environmental setting chosen is an allotment area located near to the University of Bremen Campus, Germany, approx. 400m x 300m. The setting is outside and in an urban area although somewhat removed from a standard urban environment. An aerial view of the setting is shown in Fig 4.3, and a typical view of a path is shown in Fig 4.4. The setting comprises a rectilinear grid path structure with several prominent landmarks and numerous repetitive allotment gardens in rows. With the exception of the path connecting 'Post Box' to 'Sports Centre', and a slight change of direction in the path connecting 'Hotel Munte' and 'Housing' all paths intersect at right angles. There are no visual clues or landmarks that enable global orientation, and most landmarks were not visually prominent from one location to another.

Fig 4.3 Satellite image of setting

Fig 4.4 Photo of path

4.4.2 Participants

Twenty-four participants participated for an honorarium of 7.50 Euro per hour. There were twelve female and twelve male subjects. Subjects came from a range of backgrounds, and had a range of academic and non-academic training and ages. Each subject was required to complete a Santa Barbara Sense of Direction test or SBSOD (Hegarty et al. 2002) prior to starting the experiment, to test for individual differences. The experiment took place mostly in German language, the mother tongue of the participants.

4.4.3 Design

The experiment comprised of two training conditions with twelve subjects per condition. None of the subjects had any prior exposure to the environmental setting. In the first condition; map subjects were seated in an office not connected to the environmental setting and asked to learn a map of the allotment area. In the second condition; mobile map subjects learnt the environment through a navigation learning phase which took place in the environmental setting itself. Once both groups of subjects had completed the learning task they were then asked to complete a series of estimation tasks in the environment. Once they had completed these tasks both groups of subjects returned to the office to complete a location test.

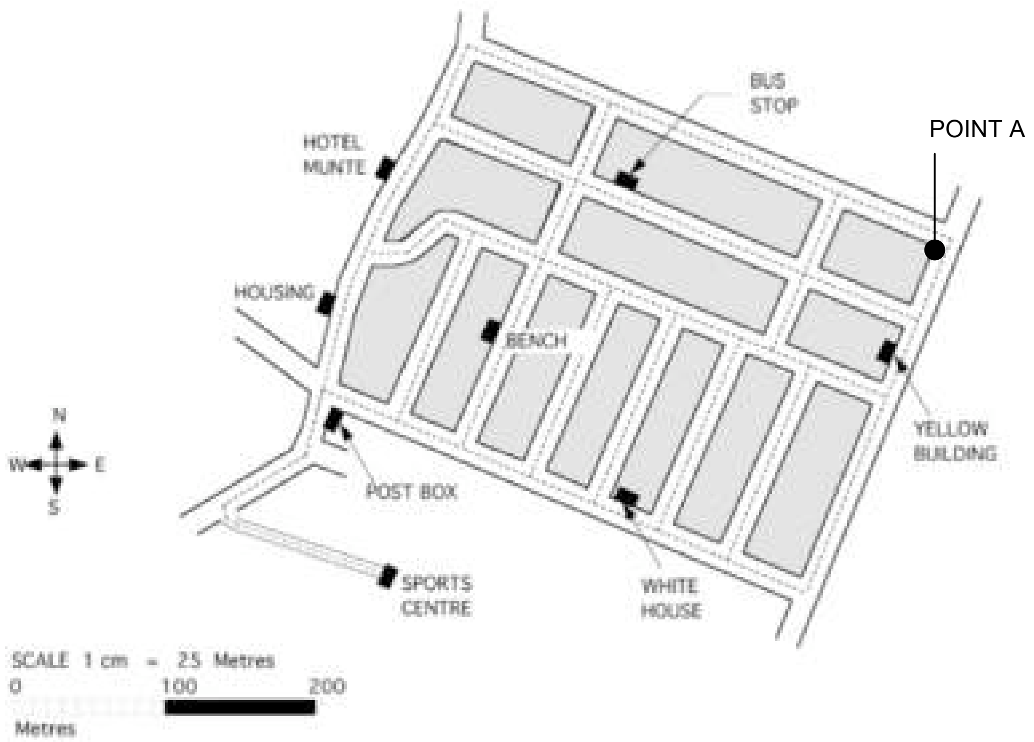
The test comprised forty-two pairs of locations. The first location of each pair was designated the start point, the second location the destination. The forty-two pairs included six start points (Post Box, Housing, Hotel Munte, Bus Stop, Yellow Building, White House) and seven destinations (Bench, Sports Centre Entrance and the remaining five start points). For each item the subjects performed five estimates: orientation (pointing to the destination from the start point along the paths), route distance (the distance from start point to destination) and Euclidean distance (the straight line distance from start point to destination).

4.4.4 Procedure

Participants were tested individually. The experimenter informed each participant that the purpose of the study was to assess the accuracy of people's spatial knowledge given different types and amounts of learning experience. The first task the participants were asked to undertake was to complete a German version of the Santa Barbara Sense of Direction questionnaire (hereafter SBSOD) (Hegarty et al. 2002) to test self-report of spatial ability.

Learning Phase

Each map-learning participant was told that she was to learn the map of the environmental setting (shown in Fig 4.5), including the layout of the paths, and the names and locations of the landmarks.



Destination	Nr.
Post Box	1
Housing	2
Hotel	3
Bus Stop	4
Yellow Building	5
White House	6
Bench	7
Sports Centre	8

Fig 4.5 The map of the environment used in the map condition (Point A was not on the participant's map)

Although the map contained scale information, the experimenter did not instruct the participant to learn metric distances. Each participant studied the map on a series of study—recall trials. On each trial, the participant was given a copy of the map to study for two minutes. At the end of this time, the experimenter removed the map and asked the participant to re-draw the map on a blank piece of A4 paper. After the participant had completed the drawing, the experimenter provided feedback to the participant on the correct and incorrect features of the map. The participant then studied the map for another two minutes. The study-recall cycle was repeated until the participant had depicted the topological properties of the map and labelled them correctly.

In the second condition, mobile map the participants were taken to the environmental setting at point A (indicated on Fig 4.5). They were then introduced to the mobile map navigation device, and the basic features. The map could be scaled in and out, but stayed in same North-South orientation on the screen of the device throughout the task. The mobile device consisted of a mobile mapping software application, Route 66 running on a Nokia 6630 mobile phone (see Fig 4.6 and Fig 4.7).

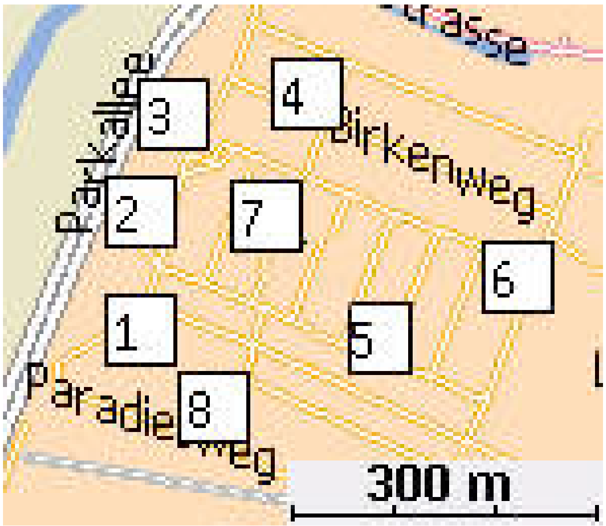


Fig 4.6 Screenshot of the map of the environment used in the mobile map condition

Fig 4.7: Map Interface on mobile device

The mobile was linked to a Bluetooth GPS, which enabled the interface to indicate the participant's real-time location on the map with a moving dot. The numbers 1, 2 etc. were explained to the participants as corresponding to a list of eight locations, the names of which the experimenter gave to the participant on an accompanying sheet of paper. In the learning task the experimenter first took the participant to location 6 and then asked them to find the next location, and this was repeated until the participant had visited all eight locations on the map. To control for order effects half the participants learned the environment in a clockwise order, and half in an anti-clockwise order. After visiting all eight locations the participants returned to point A. The participant was then asked to complete the same study recall task as completed by the map participants, although the mobile map participants only had access to the mobile map in a static condition, and they completed the task in the environmental setting.

Estimation Phase

For the estimation task, the experimenter took each participant to the first start point, the Post Box. The experimenter gave a cardboard compass wheel which contained rays numbered from 0 to 350 in ten increments to hold in front of them. The wheel was oriented along (i.e. parallel to) the short axis of the paths. This is approximately Northeast in direction on the map shown in Fig 4.5. Thus, at all start points the 0 ray was parallel or perpendicular to the paths. The experimenter then asked the participant to face in the direction marked 0. To aid the participant in estimating distances, the experimenter told the participant that the route distance from the centre of the Housing to Hotel Munte was one hundred metres. The experimenter then informed the participant that she would read to him/her a succession of locations within the environmental setting in a random order. For each of these locations (destinations) the participant was to perform three estimates. First, the participant indicated to the nearest degree the direction to the destination, using the compass. Second, the participant estimated the distance in metres to the destination along the ray indicated by the previous judgement (i.e. the Euclidean distance). Third, the participant estimated the distance in metres to the destination along the shortest path. When the participant had performed the seven sets of estimates from the Post Box experimenter led the participant to the next start point, Housing. The order of the positions from which participants made their estimates was varied, so that half of the participants completed a clockwise route and the other half of the participants an anti-clockwise route in the test phase.

4.4.5 Hypothesis

The first hypothesis for the experiment was that mobile map users should outperform the map users on both distance and direction estimation tasks, because they are provided not only with information from a survey perspective, but also with direct experience from an ego-centric perspective of navigation, including proprioceptive feedback on distance travelled by foot. The automated GPS-based localization in the mobile map should help them to integrate both types of information fairly easily, allowing them to provide robust estimates in testing.

Yet this positive effect of mobile maps may not be found if the attentional aspects of the mobile device interaction outweigh then benefits described above. So a second, alternative hypothesis suggests that mobile map participants might perform even worse than map users across the estimation tasks. This is because it is proposed that the participants may attend to the device too much whilst in the environment, which will affect the degree to which they learn about the space. If they do not leverage the advantage of combining direct experience and map access, the smaller screen size of the mobile device may further limit their learning from the mobile map.

4.5 Results

4.5.1 Learning Phase

Qualitative Analysis of Participants Sketch Maps

During the learning task, the map participants spent an average of 18.3 minutes referring to the paper map in the office setting. This was the time taken to complete the study-recall task until it was deemed that they had learned the map. This time measurement therefore also included time in which the participant drew the map as well as time learning it. The mobile map participants, who referred to the mobile map in the environmental setting, spent an average of 46.8 minutes with the map to complete the learning task in the environment. This time measurement refers to the number of minutes the participant took to complete the learning task from start to finish. It did not include the time spent drawing the map in the study-recall task, as this was essentially an additional task at the end of the learning phase. The length of time each mobile participant spent actually interacting, i.e. looking at the screen, with the mobile map varied was not recorded in this study.

The maps drawn by the participants in the learning phase were qualitatively studied for schematic differences. There were clearly identifiable differences between the characteristics and informational quality of the maps depended on whether the participant had learned the environment using the map or the mobile map. Consequently, it appears that the basic quality and features of knowledge acquired by the two groups in the learning task is different. Mobile map participants (for example see Fig 4.8 – for a full set of maps drawn refer to Appendix C-1) typically indicated a route, with a series of sequential landmarks or cues. In this case the configuration of the environment is not shown, and no features were indicated which were not on the route. None of the mobile map participants redrew the map with the layout facing true 'North-up' despite the fact that they had accessed a map representation which was orientated 'North up' throughout the learning task. In addition all the map participants rotated the map so that the paths were orientated parallel to the x,y axis of the paper sheet on which they drew the map (see Fig 4.5), although the paths on the mobile map device were orientated at an angle of approximately twenty degrees to the y axis (i.e. true orientation of environment to North-up).

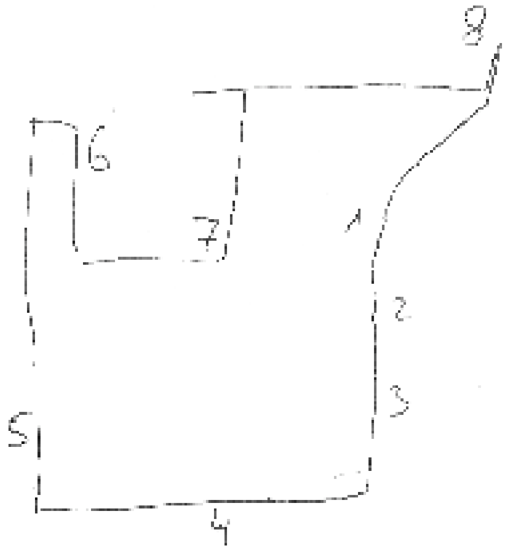


Fig 4.8. Example of initial map drawn by mobile map participant in learning task

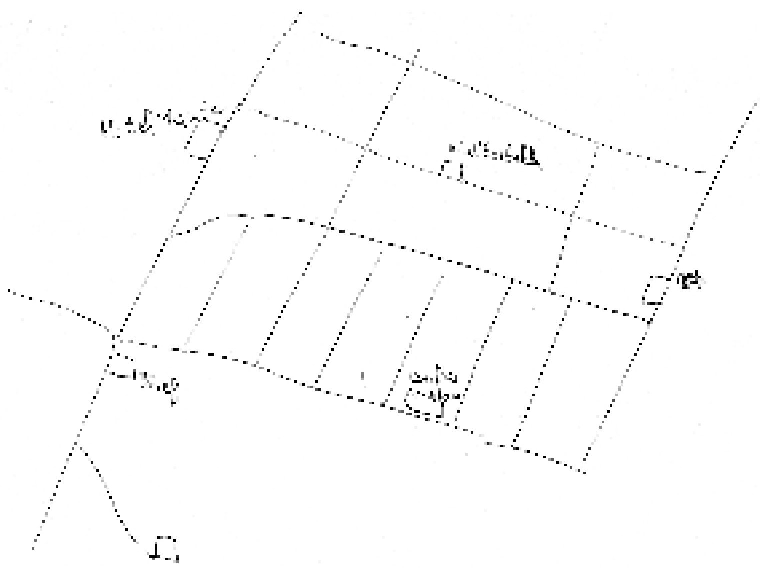


Fig 4.9. Example of initial map drawn by map participant in learning task

In contrast the map participants (for example see Fig 4.9 - for a full set of maps drawn refer to Appendix C-1) typically redrew the map to depict a clear survey structure onto which landmarks and environmental cues are placed. All the map participants redrew the map with the same orientation as the original map they had learned i.e. in 'North-up' orientation. This suggests that the map format enabled participants to very quickly assimilate a strong and stable image of the environment in the learning task.

Route Sequence Learning Effects

We checked mobile map participant's performance for links between spatial 'episodes' in the learning task and those in the estimation task. For example if the participant undertook the learning task in a clockwise order the destinations were learned in the following sequence: Yellow Building, White House, Bench, Sports Centre, Post Box, Housing, Hotel Munte. In this case an 'episode' would be 'Yellow Building to White House' i.e. two destinations learned in sequence. However the number of 'episodes', which lay between destinations in the learning task does not correlate with the performance on the estimation task either for orientation, Euclidean or route distance ($r = .002$ to $.073$, all $p > .050$).

Task Sequence Learning Effects

We also tested for the learning effect during the estimation task; the task sequence effect. There were no significant differences found (all $p > .10$). This indicates that the sequence in either the learning task or estimation did not have a significant effect on the participant's estimations, and that as such the knowledge acquired through learning map was that which the participants were accessing in their estimation tasks. Despite the short learning phase they were relying on the 'map in their head' and not falling back onto environmental cues or features to make their estimates.

4.5.2 *Self Assessment of Spatial Ability with SBSOD*

The analysis of the SBSOD scores revealed no significant differences between the two groups (Map participants: Mean: 4.73, Standard Deviation (SD): .45; Mobile map participants: Mean: 4.57, SD: .34; $t(22) = .990$, $p = .333$, Cohen's $d = .39$). According to their self-assessment, the participants did not differ systematically in spatial ability between the two groups. Looking at both experimental groups together, correlations of the SBSOD with the Euclidian and Route distance estimates are small and not significant ($r < .26$, $p > .22$). The SBSOD score correlates significantly with pointing performance ($r = .439$, $p = .032$), so it does appear to capture some of the participant's spatial abilities. However the correlations are not strong overall, which indicates that participants' self-judgement only partly captures their spatial abilities regarding learning metric relations of the space9. For the following analyses of the map vs. mobile map groups, we primarily report analyses independent of the SBSOD scores and include SBSOD scores as covariates for key analyses.

[9] The low correspondence between SBSOD scores and spatial performance has also been observed in several other studies with German-speaking participants (e.g. Hölscher et al 2006). Currently validation studies are under way to identify whether cultural differences between European and US-American participants are responsible for lower internal consistency of the German SBSOD version.

4.5.3 Orientation Estimates

Orientation Task

We tested the predictions for the orientation task by contrasting the average angular error between the true and estimated orientation of destinations for the map and mobile map participants. On average the difference between correct and estimated distance being small. The average angle of error for map participants was 16.31 degrees, and for mobile map participants 16.58 degrees (t (22)=.12, p=.905, d=.05, with SBSOD as a covariate: F (1,21)=.375, p=.547) - see Table 4.1. The same pattern of results was obtained for those destinations that were visible to the participant, compared to the destination invisible from the current location.

Type of experience	Angle error
Map	16.31° (SD = 6.50)
Mobile map	16.58° (SD =3.93)
Thorndyke and Hayes-Roth (hereafter T&HR) map	40°
Thorndyke and Hayes-Roth (hereafter T&HR) navigation	19°

Table 4.1: Angular error for orientation judgments

However when we investigate the effect of the destination on the estimation performance we find differences between the two experimental groups. Indeed there is a significant difference between the estimation of mobile map users between the destinations 1, 2, 3, 4 (see Fig 4.5 for locations) (M = 13.97, SD = 4.01) and 5, 6, 7, 8 (M = 18.95, SD = 4.66, t (11) = -4.57, p = .001, d = 1.15 (a large effect size according to Cohen (Cohen 1988)), while for the map users no reliable difference between these groups of destinations was observed (M = 15.00, SD = 4.68 and M = 17.50 SD = 8.49, respectively; t(11)=1.76, p=.105, d=.36 (weak effect size)) - see Fig 4.10.

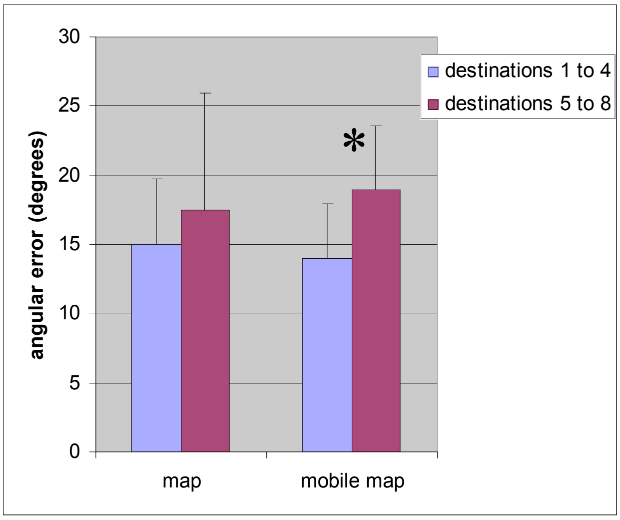


Fig 4.10 Accuracy of Orientation Estimates Dependent on Destination

4.5.4 Distance Estimates

Euclidean Distance Estimates

The difference between the estimated and actual distances is large (map: M = 69.73, SD = 20.47 m, mobile map: M = 94.33 m, Standard Deviation (SD) = 49.76) – see Fig 4.11. There is also indication of a skewed distribution around the median for mobile map (map: 67.89, mobile map: 75.90).

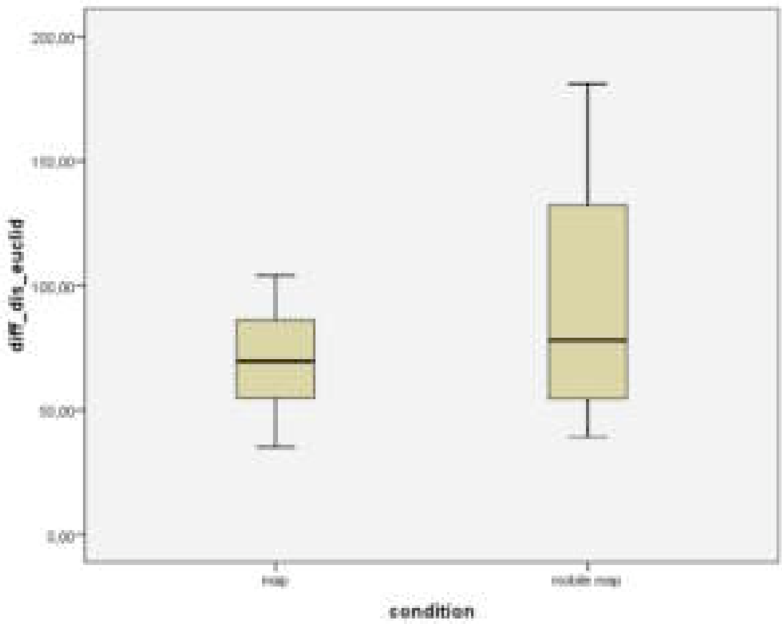


Fig 4.11: Difference of estimated and actual Euclidian distances. Boxplot indicates medians (thick line), 25th and 75th percentile (lower/upper end of box) and smallest/largest valid value. Data is aggregated by participants (graphic shows distribution of mean values per participant).

Both groups underestimated the actual distance more frequently (map 65%, mobile map 73%) than overestimating it (correspondingly 35%, 27%). Between the two groups the relative differences were compared (see Table 4.2), and were found to be non-significant (map: 32.74, mobile map: 40.21, $t(15.96) = -1.27$, $p = .222$; using SBSOD scores as a covariate also has only limited impact: $F(1,21) = 2.65$, $p = .119$).

Type of experience	Euclidean distance error
Map	32.74 (SD = 25.09)
Mobile map	40.21 (SD = 28.34)
T&HR map	32.8
T&HR navigation	32.3

Table 4.2: Average error in Euclidean estimates

Looking at individual tasks separately, only 2 of 42 tasks yielded significant differences (largely due to high inter-individual variance). Yet in the majority of the tasks the map users performed numerically better (with an average effect size of d = 0.46), whilst the mobile map users performed better only on one-quarter of the tasks and for these the differences are much less pronounced (average effect size: d = .20). The correlation between estimated and actual distances equally high in the two groups (map: r = .78, mobile map: r = .79). This pattern is independent of the testing method, whether parametric or non-parametric, and also independent of whether the destination was visible from the start point or not.

Route Distance Estimates

The difference between the estimated and actual distances is larger than that for Euclidean distance (map: M= 98.39, SD = 16.55_m, mobile map: M = 135.90, SD = 59.23_m). Both groups underestimated the actual distance more frequently (map 71 %, mobile map 72 %) than they overestimated (correspondingly 29 %, 28 %).

Type of experience	Route distance error
Map	31.86 (SD = 5.06)
Mobile map	42.26 (SD = 17.26)
T&HR map	35.8
T&HR navigation	26.2

Table 4.3: Relative error (percent) in Route Distance estimates

The average of the systematic differences was for the map -43.55 meters, and for mobile map -50.27 meters. The relative differences were tested between the groups, which yields a statistical trend (map: 31.86 %, mobile map: 42.26 %, t(12.88) = -2.0, p = .067, d = .82, - see Table 4.3). However when we use the SBSOD as a covariate a significant difference between map and mobile map groups is revealed: F (1,21)=5.47, p=.031).

Looking at individual tasks separately, we observe statistically significant differences for only 2 of 42 tasks. But again a clear tendency becomes visible: in 90 % of the tasks the map users numerically outperform the mobile map users, confirming the parametric test above.

The overall difference between Euclidean and route distance estimates is quite small, and provides a statistical trend only within the group of mobile map participants (40.21 + 28.34 % vs. 42.26 + 28.57, t(11) = -1.91, p = .083, d= .12) – see Table 4.4.

Type of experience	Euclidean Error	Route Distance Error
Map	32.74 (SD = 25.09)	31.86 (SD = 5.06)
Mobile map	40.21 (SD = 28.34)	42.26 (SD = 17.26)

Table 4.4: Relative error (percent) in Distance Estimates

Dependence on the number of legs: We tested the estimation results for the effect of route complexity (number of legs), to investigate the type of knowledge acquired. Generally the relative deviation on pointing and distance estimation (see Fig 4.12 and Fig 4.13) does not increase with the number of legs (route segments that connect the current and the destination point).

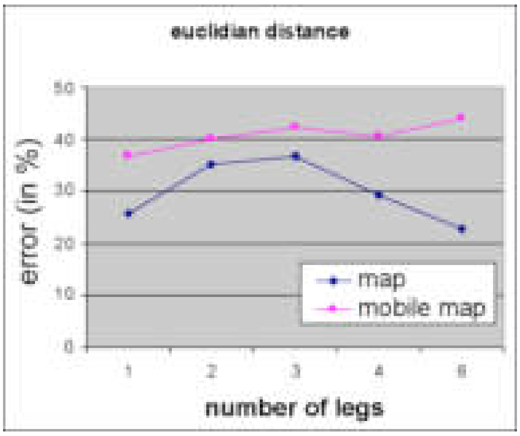


Fig 4.12. Euclidean Distance estimation error

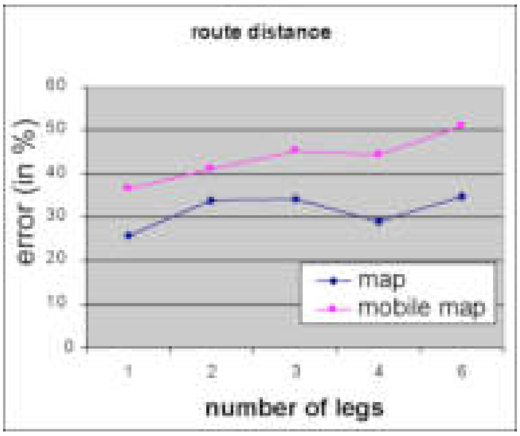


Fig 4.13. Route Distance estimation error

For map participants there did not appear to be any effect of the route complexity on the accuracy of the Euclidian or Route distance estimate (distribution approx. 32 - 33 %). Only the mobile map participants show a consistent negative trend in their distance estimations with increasing complexity of connecting routes (see Fig 4.14 & Fig 4.15).

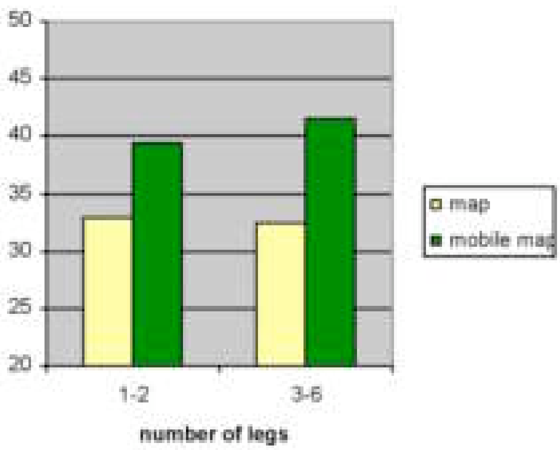


Fig 4.14: Relative error (percent) in Euclidean estimates, showing dependence on no. of legs

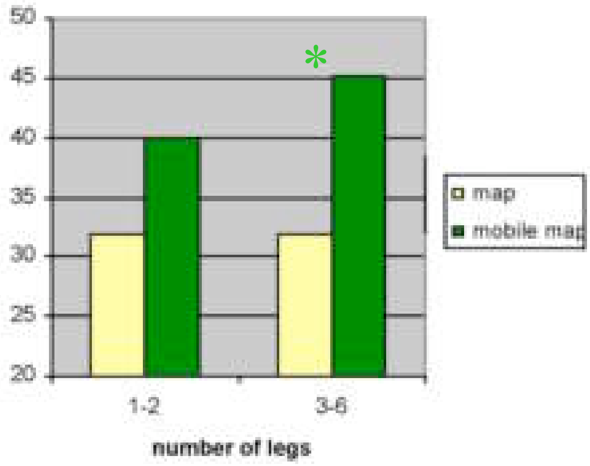


Fig 4.15: Relative error (percent) in Route Distance estimates, showing dependence on no. of legs

Mobile map participants generally made larger estimation errors than map users, and they made greater errors in route distance estimates when compared with Euclidean distance estimates. For the route distance estimates on complex routes, the differences for mobile map participants ($M = 45.29$, $SD = 19.24$ %) are significantly greater than for map participants ($M = 31.95$, $SD = 28.39$ %) ($t(14.47) = -2.00$, $p = .046$) - see Fig 4.15. This effect can be classified as large ($d = .89$).

4.5.5 Cognitive Maps

Reconstructing Participants Cognitive Maps using Least-Squares Method

To obtain a more aggregated measure of participants' cognitive maps derived from orientation and location judgments, we reconstructed participants' cognitive maps of the various locations using combinations of estimates for each location, following a method suggested by Thorndyke and Hayes-Roth (Thorndyke & Hayes-Roth 1982, p. 583). For example, on the orientation task, each participant pointed toward the Yellow Building from six different locations. Each of these estimates can be characterized as a line passing through the start point (x,y) at the pointing angle indicated by the participant. Each of these lines can miss the true location of the Yellow Building for several reasons: a) when pointing the participant may misjudge his/her local position and/or heading, b) the participant may have memorized an incorrect location of the Yellow Building, c) further noise in the data, e.g., due to misreading the instrument. The purpose of the following analysis is to separate heading error (a) from metric configurational knowledge about the setting (b). While Wang & Spelke (Wang & Spelke 2000) obtain such a separation for each individual pointing episode, the method devised by Thorndyke & Hayes-Roth combines all six estimates toward a destination into this process in order to attain more robust results:

The (known, true) coordinates of the starting locations and the pointing directions measured at each of these locations are projected into a Cartesian xy coordinate system, yielding six lines. Using the least-squares method (we use an implementation by Johnson (Johnson 2004)), one can determine the point in space closest to all six lines (in terms of angular difference). The co-ordinates of this point are then taken to be the best estimate of the location of the destination point in the individual participant's cognitive maps. Two measures are derived from this point estimate: the accuracy of the point (defined as the Euclidean distance to the coordinates of the true location) and the consistency of the estimate (defined as the Root Mean Square Error (RMSE) of the estimate obtained from the least-squares method; i.e., how far the pointing lines diverge from the calculated coordinates). The accuracy measure captures systematic distortions in the pointing to a destination across a series of pointing locations (distance of imagined location from true location), while the consistency score is an indicator of fluctuations in pointing to that destination from several locations. The accuracy measure captures errors in the mental representation of spatial configuration (configuration error), while the consistency score picks up local disorientation between locations or heading error. Outliers were identified and eliminated for each destination separately with a box-plot analysis.

Accuracy of Participants' Cognitive Maps

Across all destinations combined we found no statistically reliable differences between map and mobile map users in t-tests or analysis of variance (ANOVA). The descriptive statistics suggested that for some destinations there might be an individual difference between the two groups map and mobile map - see Fig 4.16.

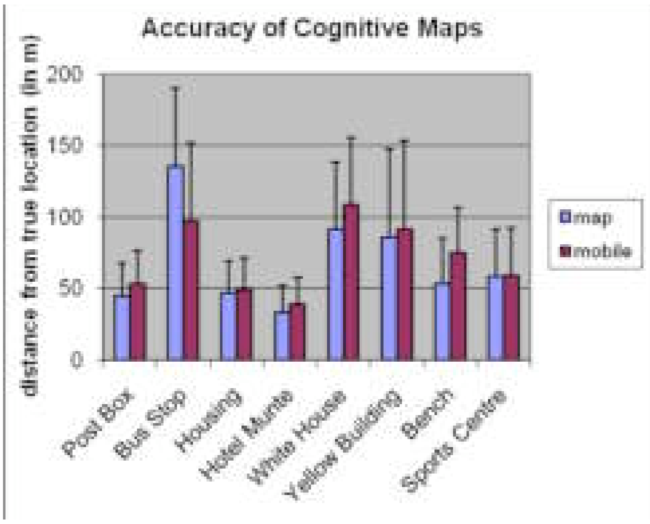


Fig 4.16: Accuracy of Orientation Estimates Dependent on Individual Destinations

Yet none of the tests of single locations was significant (Destination 4, 'Bus Stop' showed the relatively strongest, yet non-significant difference ($t(21) = 1.68$; $p = .108$), with map participants estimating less accurately than mobile map participants. Once again we established an impact of grouping the destinations: mobile map users perform significantly better on destinations 1-4 ($M = 60.24$, $SD = 19.52$) than they do for destinations 5-8 ($M = 88.76$, $SD = 35.53$; $t(11) = -2.70$, p

= .020, d = .99 (large effect size)), whereas for map users no difference between these groups of destination was observed (M = 68.09, SD = 26.52; M = 78.13, SD = 37.96; t(11) = -1.10, p = .293, d = .31 (weak effect size)).

Consistency of Participants' Cognitive Maps

We employed the Root Mean Square Error (RMSE) as a measure of the consistency of the estimations to each destination. The consistency of participant's estimates towards most destinations hardly differed between the two groups (see Fig 4.18), with the notable exception of destination nr. 5 'Yellow Building', where mobile map participants show lower consistency (marginally significant in non-parametric test: Mann-Whitney-U = 39.0; p = .057; but not parametrically: t (22) = -1.51; p = .144). A visualisation of the results for one destination (see Fig 4.17 and for a full set of results refer to Appendix C-2) shows how the distribution of estimates is scattered around the actual point.

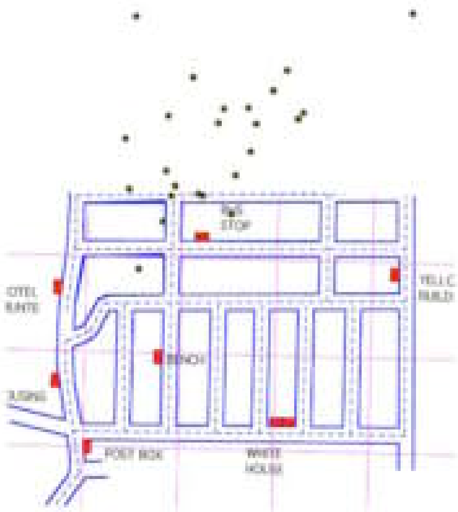


Fig 4.17. Accuracy of Participants' Cognitive Maps for destination Bus Stop

This representation does not distinguish between the two groups of participants, but gives an indication of the accuracy range for estimates on one particular destination. In particular it shows a tendency also revealed in the results for other destinations of the range of error to 'cluster' in relation to the true point. For example in Fig 4.17 above the estimates tend to cluster around the area 'North' of Bus Stop, rather than being scattered randomly around the destination.

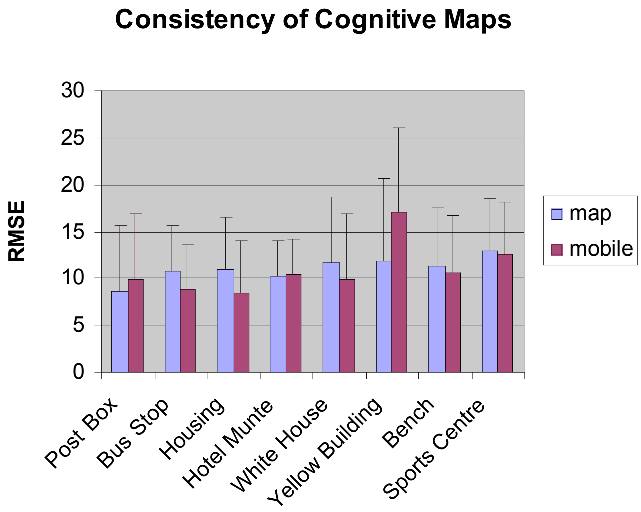


Fig 4.18: Consistency of Orientation Estimates Dependent on Individual Destinations

A further qualitative measure of the consistency of participants' cognitive maps was obtained through representing the distribution of error as ellipses on a scaled plan of the setting (see Fig 4.19, where 1 represents map participants and 2 represents mobile map participants). From these diagrams a pattern emerges where map user's estimates were less consistent, since the size of the ellipse is larger for the map participant's for many of the destinations. This is particularly the case for the destination Hotel (see Fig 4.21), where there is a marked difference. On further examination it was found that these errors were primarily the result of two participant's estimates. The key aspect of these diagrams is the qualitative results were not filtered for outliers. Therefore these results show the effect of outliers in the map group on the distribution of consistency of estimates. Thus, when all participants are included it can be seen that the map subjects were generally more inconsistent in their estimates. The one exception was the destination Yellow Building (see Fig 4.23), where mobile map subjects appeared to estimate less consistently. Consequently the results given in Fig. 4.18 above show that although these diagrams indicate map user's did not perform as well as mobile map user's, in fact the outcomes are skewed by a small number of participants in the map group who consistently estimated poorly. This was not the case for the mobile map users, where there were noticeably fewer outliers.

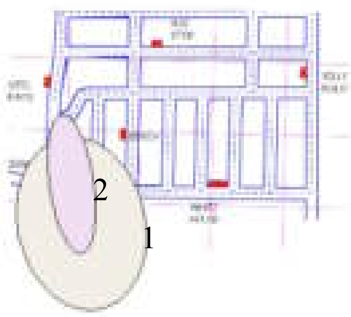


Fig 4.19. Consistency of Participants' Cognitive Maps for destination Post Box

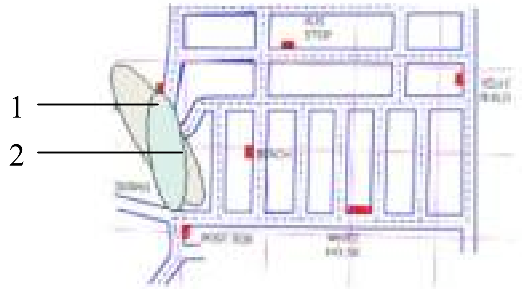


Fig 4.20. Consistency of Participants' Cognitive Maps for destination: Housing

The map users estimates generally exhibit a tendency to estimate 'beyond' the extent of the environmental path framework, rather than within it. This can be seen in destinations Yellow Building and Bus Stop (see Fig 4.23 and Fig 4.22), where the extent of the ellipse extends into the 'white space' beyond the destination and not across the other destinations in the environmental framework. A further pattern that can be observed across all the destinations is the orientation of the ellipses. These show an almost clockwise distribution of the angle of the ellipse for the destinations. For instance the orientation of the error for Sports Centre is due South, for Yellow Building it is easterly and for Hotel it is westerly. The reason for this could be an indication of the fact that the estimation process was somehow interlinked in character, so that estimations to individual destinations were not independent, but essentially relational in the mental image of the participant's. In this manner, participant's estimated to the destinations with an idea of the 'limits' of the spatial framework they were working within and also a concept of the location of all the destinations in relation to one another. They then sought to place the individual destination within this framework, but due to errors the framework can be said to have 'stretched' and rotated away from the true locations.

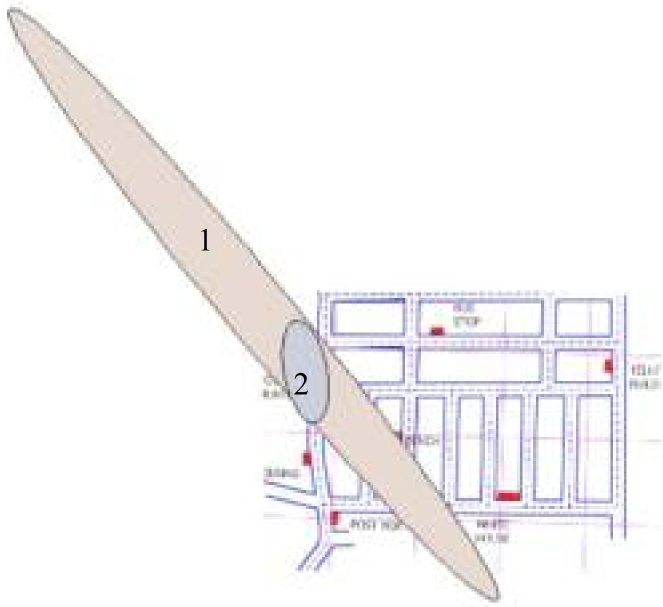


Fig 4.21. Consistency of Participants' Cognitive Maps for destination Hotel

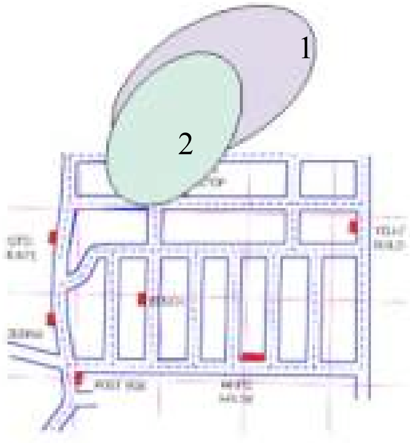


Fig 4.22. Consistency of Participants' Cognitive Maps for destination Bus Stop

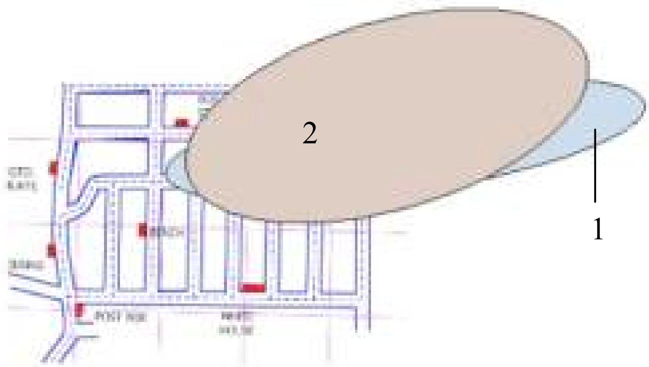


Fig 4.23. Consistency of Participants' Cognitive Maps for destination Yellow Building

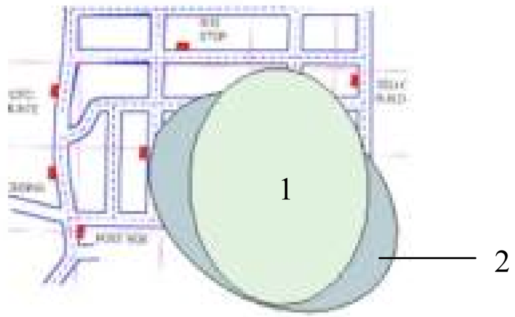


Fig 4.24. Consistency of Participants' Cognitive Maps for destination White House

The destination Bench (see Fig 4.25) is the only condition where the diagrams above show that consistency of the estimates is poorer for mobile map participants. This destination proved to be more challenging for the mobile map user's than map users.

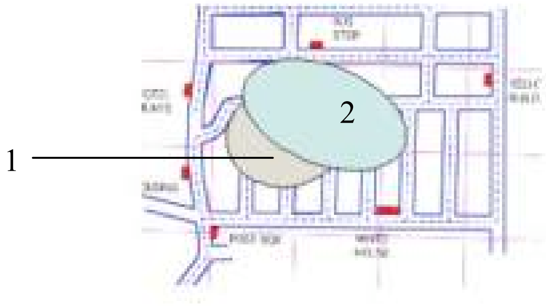


Fig 4.25. Consistency of Participants' Cognitive Maps for destination Bench

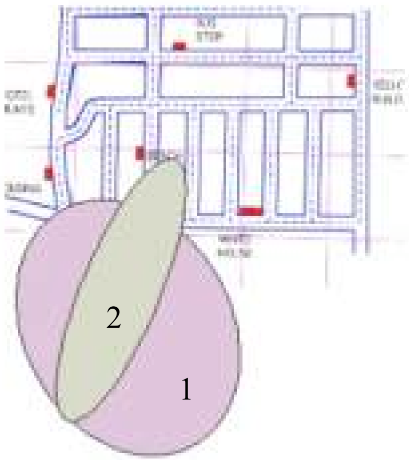


Fig 4.26. Consistency of Participants' Cognitive Maps for destination Sports Centre.

4.6 Discussion

4.6.1 Maps, Mobile Maps and Navigation

Overall, none of the two groups outperform the other as clearly as one may have expected based on the conceptual difference of learning purely from a map vs. an integrated experience of navigation and digital map support. Route distance estimates were overall better in the group that had no direct navigation exposure to the setting in training, a finding that is at odds with the original T&HR study and provides strong indication that digital navigation support is not unequivocally favourable for spatial learning. In line with Wang & Spelke (Wang & Spelke 2000) one could suspect that the mobile map participants relied mostly on their navigation experience rather than the digital map supplement. Continuous 'spatial updating' of the relative positions of eight widely dispersed landmarks would be seen as highly problematic in their account, while map users could rely on a fixed survey representation rather than ego-centric experiences. But in a 'spatial updating' account one would expect clear effects of training and test order of locations, which were not found in our study. Also, such an account would not account for the relative difficulty of certain locations independent of task order as described below.

Perhaps even more importantly, it was found that mobile map subjects exhibited comparatively poor performance in both orientation and distance estimation for complex routes. In addition, mobile map subjects performed significantly worse on estimating orientation for four destinations, which were essentially more 'difficult' to estimate. This same pattern was observed when we tested the accuracy of participants' cognitive maps, whereas map users exhibited similar performance regardless of destination.

We propose that the regular grid-like and fairly simple layout of the setting appeared to reduce the differences between the two groups, and indeed studies have shown that learning of simple layouts can reduce the differences between map and direct learning experience (Richardson et al. 1999). If we refer back to the original T&HR study, participants made their estimates at the equivalent locations as the study described here, but since the setting was the interior of a building the participants estimated in a closed room without visual reference to the surrounding space. In this study participants were able to visually reference their position whilst making estimates (although there were no global landmarks).

This would account for the good performance of both groups in the orientation task (equivalent to navigation participants in the original T&HR study), and would also explain for the poor performance of the T&HR participants map users. A further factor to consider is that given the differences between the two groups in the learning task this is in itself indicative of different types of knowledge. The mobile map participants spent an average of fourty-six minutes in the environment whilst using a corresponding map. In theory, they had considerably more information available for learning, including the map-based information including automated self-localization (GPS), visual information about the actual environment form egocentric perspective and proprioceptive feedback about walked distances. By contrast, the map users interacted with the map in a remote setting, and only took around eighteen minutes to learn it, without any opportunity to relate it to an egocentric experience of the environment.

Consequently, given the training modalities and information provided, mobile map users should have had an advantage in the estimation tasks, unless other factors outweigh such an advantage. But in fact the mobile map participants failed to show superior performance, generally performing worse than the map users. However we have shown that learning in the environment was not linked to the route they took during the learning or testing phase task, which indicates that mobile map participants were acquiring a mixture of landmark, survey and route knowledge. This suggests that their learning was as a result of the way they interacted with the mobile map interface and not just coincidental learning from their experience of the setting. In our analysis we also found qualitative differences between the groups, in particular in the comparison of the participant's sketch maps form the learning phase, which exhibited consistent, but differentiated features and level of detail between map and mobile map participants.

In general when we compare back to the original T&HR experiment we can extrapolate the results to make assumptions about the performance of navigation participants when compared to map and mobile map users. From this experiment this would suggest that navigation participants would perform best, followed by map participants and then mobile map in route distance estimation. For Euclidean estimates, map and navigation participants were fairly similar in the T&HR study, but our mobile map participants appeared to perform less well. Overall mobile map subjects indeed performed worse in the majority of tasks, which suggests that for the estimation task in this study their knowledge was the weakest when compared those with map and navigation learning experience. We argue that the disadvantage of mobile map participants can be attributed both to differences in the spatial schema acquired in the learning phase and to distracting features of the mobile map device. These aspects are discussed in detail in the two subsequent sections.

4.6.2 Models of Knowledge

Generally the results for distance estimation showed that mobile map users made more pronounced errors. But mobile map users performed equally well as map users on orientation estimation, which failed to support the hypothesis. At first this combination of results may appear strange; how can an individual acquire knowledge about spatial relations, but have such poor metric knowledge? A first reason for this is that knowledge is not formed according to the 'classical' framework for knowledge acquisition (e.g. Siegel & White 1975), as learning is in fact much more complex. Knowledge is not acquired in the sequence of landmarks, routes and then survey, but according to Montello in fact some aspects of survey knowledge can be acquired quite quickly within a new environment (Montello 1998). We found that the participants who were new to the environment were able to demonstrate a mixture of landmark, route and survey learning. A second reason we propose for this based on differences in the type of configurational knowledge. Although the map representation learned by the two groups had similar features, the way that it was presented and delivered to the participants fundamentally affected the spatial knowledge acquired. Map participants' performance did not change with route complexity with either Euclidean or route distance, indicating the broader, configurational nature of their knowledge. For map participants, the learned knowledge about spatial relations was preserved as a whole which enabled the individual to locate landmarks within the template-like schema (see Fig 4.27) and make fairly consistent orientation and distance estimates for all destinations.

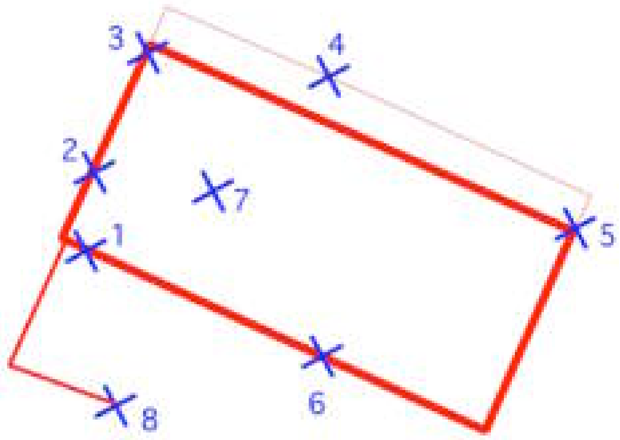


Fig 4.27. Map knowledge structure

The learned plan was simplified to position destinations within a configurational frame-like structure, so that participants framed the destinations by linking destination 3 and destination 5, so that destination 4 lay outside the main frame and was consequently poorly estimated.

Mobile map participants acquired a form of knowledge which preserved spatial relations between some closely linked destinations, and resulted in a schema structured around closely spatially linked salient landmarks (see Fig 4.28).

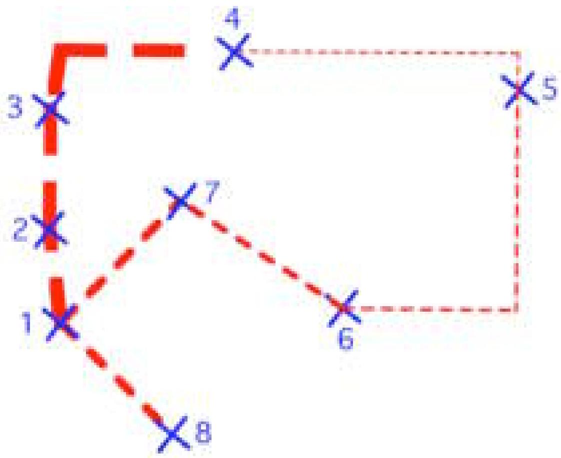


Fig 4.28. Mobile map knowledge structure

This mixture of locally coherent, but globally more loosely connected sub-sets or regions is clearly in line with the PLAN model of Chown and colleagues (Chown et al. 1995, Chown & Boots 2008) with its regionalized cognitive maps, based on topological relations and associative connections. Furthermore, the piecemeal representation is once again in line with Montello's (Montello 1998) view that survey-level and route-based representations can develop in parallel even after limited time of exposure to the environment.

Tversky has termed such representations '*spatial mental models*', which are categorical in nature and preserve coarse spatial relations coherently but not metric information (Tversky 1993). These spatial mental models enabled participants to make good estimates of some spatial relations, but were fragmented and inconsistent in nature since they retain only simple spatial relations. For this reason the consistency of the estimation to the destination of 'Yellow Building' (Nr. 5 on Fig 4.28) was particularly poor due to its comparatively more complex links to other destinations. However the lack of a stable structured configuration meant that knowledge for distances was poor and particularly for destinations that were separated by more than three legs from a start point.

4.6.3 Attention

Passive Interaction

Interestingly, it was not the graphic representation of the mobile map that distinguished it from a cartographic map in the effect on performance, but rather the delivery and attention it required of the individual. However the mental process of committing information to memory, or learning, is itself an effortful task that requires conscious attention. A seminal study by Held and Hein (Held & Hein 1963) found that learning in a spatial environment is hindered when the participant experiences it in a passive mode i.e. being led through the environment without being able to make self-motivated choices. When a participant is actively engaged in the environment then they are stimulated or motivated to learn and gain knowledge about the space in which they are moving. A mobile map essentially enables and even encourages someone using it to switch off mentally, and to become the passive receiver of information, and as such does not support learning in a constructive manner. In using a mobile map individuals essentially disengage with spatial clues in the real-world and allow the device to make decisions. In this way not only do they fail to actively participate mentally in the spatial task at hand, they are also not motivated to learn about the environment which they are in which has implications for long-term actions. If people continue to use digital spatial information delivered incrementally in the environment, then there is a real concern that people will become disengaged from the spatial world.

Fragmentation of Attention

The attention of the mobile map participants was constantly being divided between the mobile device and the environmental setting, which affected their memory. Rather than the mobile map interface disappearing into the background it seems to have the opposite effect; creating a conflict, with attention to the features of the real environment being divided and shared with attention to the interface. Since both offered different forms of information; the mobile map a survey type representation, and the environment an egocentric perspective, the participants were in a constant process during the task of trying to resolve the information from the map and the information from their view environment, and this resulted in lack of attention to the overall task.

Unstable Schema

Although the map participants spent considerably shorter time learning the map they were able to act on it fairly consistently. The key factor was that the learning effort for the map took place in a planning stage, so that the learned map was remembered as a single static clear representation. Consequently it enabled more cognitive offloading so that during the actual task the individual could focus on matching cues in the environment to their internal map. The reverse appears to be the case for the mobile map learning, which took place concurrently with information being delivered incrementally so that it was never learned as a single stable schema. A final aspect is the scale of the mobile map display, and the fact that the user was able to change the scale of map representation. Oulasvirta and colleagues report that the small scale of transformations in mobile maps may lower the informativeness and recognisability of objects (Oulasvirta et al. 2005). Since the user did not consistently view the same map representation throughout the task, this created a type of focused 'keyhole' information acquisition, so that locations were best remembered when they were literally close together in space.

4.7 Outcomes

4.7.1 Interaction with Mobile Devices

In the introduction to the approach of this study a model was described (see Section 4.3, Fig 4.2), which proposed an interaction model which represents these dynamic aspects. This model sought to create a structure for understanding the inter-relational nature of the interaction between individuals, technology and the environment. However the empirical study has shown that it is in fact more useful to focus, not on an overview of the situation as a whole, but instead on the processes which occur during the interaction. This is particularly in relation to the problem domain being studied regarding the role of technology in wayfinding situations. Although the model in Fig 4.2 is still valid, it does not adequately reflect the nature of a wayfinding situation as the result of changeful processes. For instance, this is highlighted by the fact that the change in focus of an individual’s attention during a wayfinding task fundamentally affects what is learned. The original interaction model cannot capture this quality. Therefore an updated interaction model is proposed in Fig 4.29. This model seeks to reflect the finding of the experiment regarding the format and delivery of information during a wayfinding situation. In such situations the individual’s attention is occupied in a feedback loop of planning and acting in a problem solving structure. In this process different forms of spatial information are required at different stages. In the planning stage, survey-type representational knowledge is ideal, as it provides a framework for structuring an action plan. However in the decision stage, the individual acts based on information cues from a combination of sources; knowledge from a pre-formed plan, local knowledge and background knowledge, in order to make a decision. The main emphasis at these decision nodes is on matching the knowledge available in the environment, and that offered through the mobile device. In this stage the individual may just be updating their progress of their plan, and confirming their position, but it is also the case that they may have found that they are lost, and will have to review where the plan failed and adjust accordingly. In this stage spatial information should be focused around the actual position of the wayfinder, and should present local salient features. In the action stage the wayfinder ideally will not need to access the mobile device, but will be passively gathering spatial information from the environment, which they may only use later, as recall in the decision making stage.

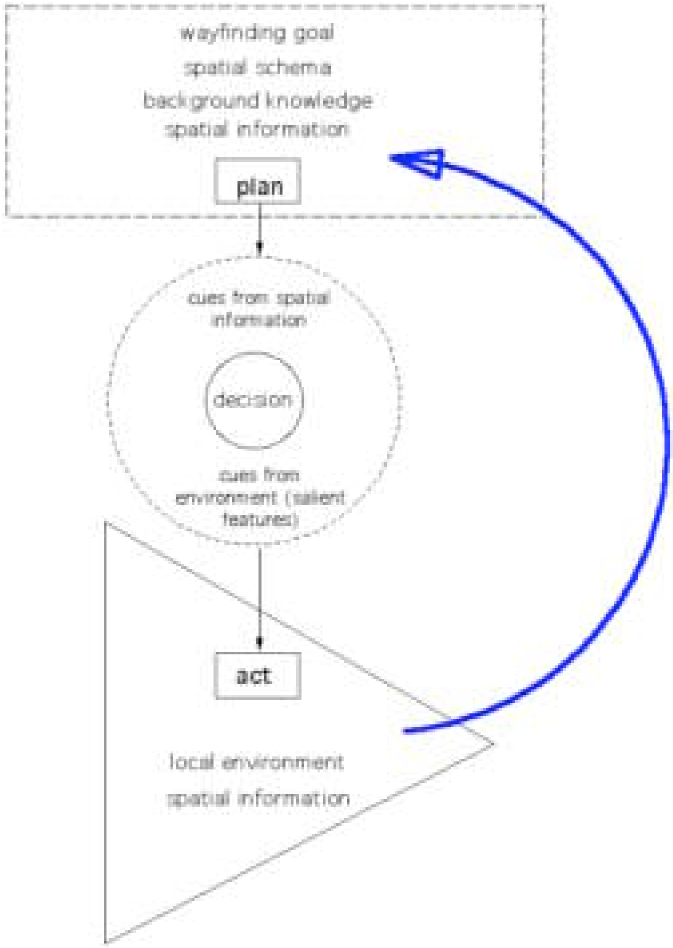


Fig 4.29. Interaction Model for Wayfinding Situations

4.7.2 *Implications for the Design of Mobile Navigation Applications*

We have identified that there are implications for learning with applications that deliver spatial information through a mobile navigation application. Mobile spatial applications tend to work on a model where the individual is not encouraged to plan a spatial task i.e. conceptualise a schematic form of information and then act on it, but instead to proceed in a task where information is delivered incrementally and without user input. Oulasvirta has highlighted this problem as an issue of fragmentation of attention, and suggested that interaction units should be shortened and dividing tasks into smaller episodes in order to decrease demands on attention (Oulasvirta 2005). A number of researchers have re-assessed interaction paradigms to propose where improvements can be made. For instance Graham and colleagues propose as an approach the adoption of a series of roles in interaction paradigms; ranging from 'guide', 'local', 'chaperone', 'buddy' through to the most automated 'captain' which would be appropriate in different task situations (Graham et al. 2004). Parush and colleagues derived proposals from empirical studies in a virtual building which found that participants who rather passively interacted with an automated system performed significantly worse than those who were stimulated to actively monitor and track their location during the task (Parush et al. 2007), indicating the role of active engagement for spatial learning. The authors suggest that despite limitations, GPS based navigation systems may be useful for certain professions such as professional drivers or pilots, since such users are self motivated to learn. In this study we focused on cognitive strategies that people employ to manage spatial tasks, and as a consequence we proposed that the model of passive interaction with such applications is not best matched to individual's schematic models of information. Obviously there are benefits of reducing the demands of working memory for cognitively offloading navigation tasks onto such applications much in the way a diary reduces the need to remember dates. But in order to support learning i.e. the transformation of working memory into long-term memory, we suggest a number of solutions which seek to respond to the problems with the model of interaction for mobile navigation applications:

Cognitive problem: passive nature of interaction

Application solution: enable user to stimulate and control the delivery of information, and require user to confirm information mid-task.

Cognitive problem: unstable schemata

Application solution: allow for planning pre-task where a fixed schematic overview of the entire wayfinding task is displayed and then can be referred back to during the task.

Cognitive problem: fragmentation of attention

Application solution: reduce task information into short episodes or chunks, which are saved in the application so that there is the opportunity for user review at the end of an episode to support memory acquisition. Capacity for application to switch off mid-task when nothing is happening to reduce visual focus on device.

Cognitive problem: lack of referencing between information delivered by application and real environment
Application solution: require user to either self-select cues from existing knowledge, self-report location or to cue match in order that the user cross references features in the application with real-world environmental features.

Cognitive problem: poor memory for distance
Application solution: display distance to destination as time, rather than distance.

On a broader level there is an issue with the delivery of spatial information through map formats. Maps are a fundamental example of how spatial information presented in an abstract manner fosters certain ways of acting in the world, which can have cognitive benefits but also drawbacks. We have identified some problems above, but mobile navigation applications also offer a great deal of potential for incorporating relevant aspects of the individual's actual situation dynamically into the task. This would support a more meaningful integration between the world in the mind of the individual and real-world conditions.

4.8 Conclusion

When we move and act in the urban environment in a motivated manner, we acquire knowledge about it, which is transformed into mental representations. These representations can be retrieved to make decisions during navigation, but we also use graphic representations such as maps and mobile maps to assist us. In this chapter we introduced an experiment, which looked at the types of knowledge acquired by an individual, depending on whether they used a map or mobile map to assist them. The study found that mobile map users performed worse than map users, particularly on Euclidean and route distance estimation, and that this was a consequence of the format and presentation of the spatial information. We examined the reasons for these differences, and stated that mobile map users acquire a fragmented set of knowledge about spatial features, whereas map users act on a framework within which features are located. The chapter concluded with a discussion of design issues with mobile navigation applications, and some possible solutions to the cognitive problems identified in the empirical study.

5

Empirical Study Two
Spatial Perception of Mobile and Wireless Technologies in Urban Environments

5.1 Abstract

The second phase of experimental study moves from the individual's interaction with spatial assistance to a focus on understanding of how space embedded with technologies is perceived and how this affects spatial behaviour. This seeks to position the knowledge investigated into a real-world environmental setting, to situate the way in which the city is experienced and conceived. The main purpose of the study is to understand how mobile and wireless technologies are perceived in terms of their spatial presence in urban public space. The study comprises three sub-studies; the first looks at perception of the spatial presence of a WiFi node in space, the second identifies the physical location in space and how this relates to urban public space. The final phase investigates the WiFi usage depending on its location in space and thus the consequential effect on spatial behaviour.

5.2 Introduction

The empirical study which follows focuses on WiFi technology. WiFi is a 'wireless' technology, which means that it enables users who access it to do so from more than one location, and without a wired connection. However WiFi is also technology that is 'fixed' in space; WiFi access may extend within a space, but it is structured around a series of nodes which are literally black boxes emitting a wireless signal that have a specific location in space. The proliferation of wireless Internet or WiFi nodes in urban environments is creating a dense communications infrastructure, which re-draws existing spatial thresholds and territories. Although such wireless access is often referred to as a wireless 'network' in reality this network is not meshed on an infrastructural level, and wireless access is in fact generated through individual, usually unconnected nodes. The nodes or routers, which are essentially black box transmitters operating on the frequency of the 802.11b standard create a region of access of between thirty two metres indoors and ninety-five metres outdoors. However the coverage over an area does not decrease evenly with respect to the source, and Wi-Fi performance decreases roughly quadratically as the range increases at constant radiation levels. Due to the extent of this region, or territory, wireless access to the node can be available well beyond the physical borders and thresholds that traditionally delineate the boundary between private and public space. The setting in which the node operates exists on multiple levels; the technological setting of the node itself, the spatial setting in which it is accessible, and the social setting in which the user interacts with the technology – see Fig 5.1.

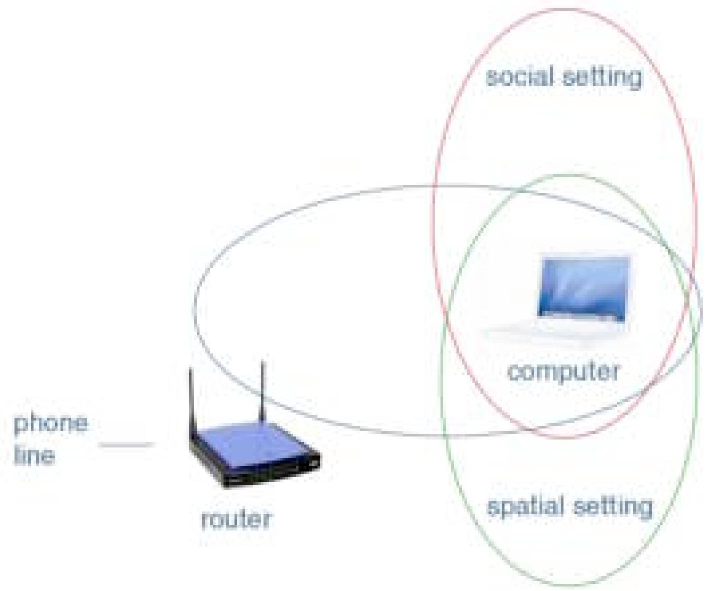


Fig 5.1: Setting of wireless node

The question this study poses is: how do individuals mentally model the environment embedded with mobile and wireless technologies when they are not inherently conceived in terms of their visual form? This three-phase study proposes that individuals interact with the environment based on conceptualisations that are derived more predominantly by the possibilities that mobile and wireless technologies offer for supporting certain types of social behaviour, than by mental 'mapping' like images.

5.2.1 State of the Art

Over a number of years some researchers have approached the problem of the lack of physical presence of mobile and wireless technologies by looking at ways of visualizing these networks; such as the work of Carlo Ratti (Ratti et al. 2005) with real-time mobile phone networks and the Equator Project with the mapping of WiFi nodes and GPS availability (Dix et al. 2005, Oppermann et al. 2006). In addition many WiFi mapping resources have been created as online resources, such as Wigle. These go some way to giving people an understanding of where the spatial presence of wireless and mobile networks overlay the space. But on another level these mappings use false metaphors, and in trying to reduce complexity create instead oversimplified models of how these technologies exist in the physical world.

An alternative approach has been taken by groups such as the Wireless Internet Project, who, rather than study existing patterns, have instead sought to create networks which they can then observe. In 2002 the W.I.P. set up an open wireless network within a public park setting in New

York, USA. The Bryant park wireless project provides free, unrestricted broadband Internet access to park visitors with the intention of changing public behaviour through the introduction of wireless availability in a park setting. This is demonstrated by the statement of Daniel Biederman, president of the Bryant Park Restoration Corporation who explained in a NY Times interview: *"We look over their shoulders a lot," Mr. Biederman said. "When I see someone using a laptop and I run up to them and say, `Hi, I'm the guy who runs the park, and I wanted to see what your reaction is to this,' it's almost like parental guidance." (*NY Times 24 November 2002).

A final method involves studies which have been undertaken to analyse traffic or volume of users in networks or collections of associated wireless nodes, such as those within a company or a university campus (e.g. Mahanti et al. 2007, Tang et al. 2000). However these tend to only analyse patterns of user behaviour, based on individuals use over time and very few have extended specifically to studying patterns of use dependent on the location of the WiFi node. When this occurs it tends to be within an easily observable social structure- such as university campus (Mehanti et al. 2007) which does not reveal general patterns of public use in urban space.

5.2.2 Scope of the study

This study focuses specifically on the use and perception of wireless Internet offered through WiFi nodes located in public space. This is because the research seeks to equate the use of public WiFi nodes with public physical space. WiFi is however increasingly offered as an option with 3G mobile phones, where access is over the ubiquitous mobile phone network and not through a WiFi node. Usage at the moment is low, but there is expectation that it will become significant; for instance twenty eight per cent of mobile phone users world-wide have used their mobile to access the internet, with this rising to four in ten adults browsing the Internet on their wireless handset in Japan (Ipsos 2006). This mobile Internet access service has blanket availability i.e. it is available wherever you can get a mobile phone signal, and as such has a different relationship to the space in which it is accessed, in the sense that it is 'everywhere'. However, this is a paying service on the mobile phone network and is therefore not covered by this study, as the focus of this work is on public free access. Correspondingly private WiFi node use is also not studied, as this is similarly a paying and non-public service.

5.2.3 Environmental Setting

The setting for the three-phase study is in a defined roughly one kilometre square area in South East London called Deptford. The area studied roughly covers a neighbourhood, which is home to a number of community-based and public arts centres, including theatres and community centres as well as public amenities such as swimming pools, schools and parks. It also has a vibrant street culture, with a twice-weekly street market, and has a lively multi-cultural local population – see Fig 5.2 to Fig 5.10.

Fig 5.2 Map of Deptford: study area (views are indicated with red arrows)

Fig 5.3. View 1:Deptford Church

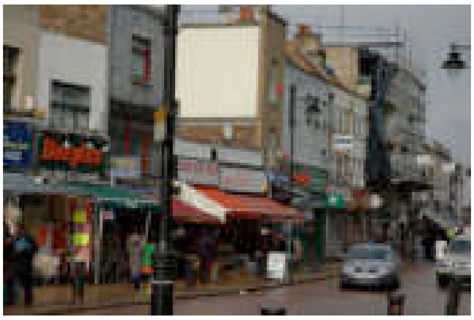


Fig 5.4. View 2: Deptford High Street

Fig 5.5. View 3: Deptford market

Fig 5.6. View 4: Private Housing Estate

Fig 5.7. View 5: Bird's Nest Public House

Fig 5.8 View 6: Creekside

Fig 5.9. View 7: Laban Centre

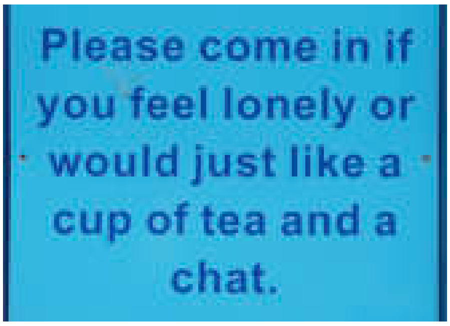


Fig 5.10. View 8: Sign outside Drop in Centre, New Cross Road

However the main reason the area was chosen for this study is that Deptford is also home to a well-organized, community-led mesh of public wireless nodes called 'Boundless'. Boundless was established during 2004, and according to Bleecker it developed out of the two initiatives which were the first to offer free WiFi access in London; the Clink Street and the Consume network (Bleecker 2004). It aims to support community development of user-owned and operated local Internet access, inter-linking residential, business, educational, cultural and digital media communities. The infrastructure and positioning of the nodes derives out of experience of how people adopt public wireless access practices. According to James Stephens, one of the founders of the project:

'Boundless consolidates theory and free network practice pioneered in the wild back then '[10]

In studying of the area of Deptford that hosts the wireless network, the setting provides a prime example of a well-established, public wireless internet access, a lively social setting embedded in a rich community, and an urban public space.

[10] Personal correspondence, 2 November 2007

5.3 *Phase 1: Perception of Presence of a Wireless Node in Urban Public Space*

5.3.1 *Introduction:*

The first stage of the study seeks to understand in more detail the nature of perception of the spatial presence of a single WiFi node. Wireless networks are structured around series of nodes. These nodes are the points at which a person actually accesses the network, and are literally devices that have a physical location. Yet in terms of their presence in space they may be viewed through an interface which shows the presence of available nodes, but are rarely present in the sense that they can be seen in a visual manner. Often they are concealed within a roof space, or a merely such anonymous devices in terms of visual appearance that they are not noticed. Yet in order for us to act 'sense-ably' in urban public space it is often useful to be able to literally find a node. The first phase of the study seeks to establish that people perceive the presence of wireless networks in public space in terms of possibilities for spatial behaviour and not in terms of purely visual conceptualisations.

5.3.2 *Method*

The first phase of the study took one specific setting within the environment; a public café offering wireless Internet access. The method combined the gathering of sketch maps together with informal interviews with participants. Sketch maps are used to try to understand how an individual conceptualises spatial configurations. The follow up interview sought to elaborate on the information displayed in the drawn sketch map and to elicit how this affected their behaviour in the space. These interviews took an ethnographic approach, a method which has proved beneficial for gathering data in real world, informal public settings such as café's (see Laurier et al. 2001, Whyte 1943, Suchman et al. 1999.) The individual data sets were then analysed to gain an aggregated overview of the range of results. The results of this study are qualitative in nature, and there was no statistical analysis of the data.

Procedure

Over a period of three days in October 2007 the usage of the café public Internet was observed. In order to capture real users of the space the study was conducted without recruiting participants in advance, but by simply approaching people who were using the Internet access in the space. The criteria for them being chosen to participate was that they entered the café space and sat within it for a period for at least fifteen minutes and used a laptop to access the free wireless internet. Once a participant was identified as suitable, the interviewer approached them and they were asked if they were willing to participate in a study. If they agreed they were first given a short introduction to the purposes of the study. Participants stayed sitting in the position in the space in which they had been working for the duration of the study. It was explained that

the study was to investigate and measure the perceived presence of the availability of the wireless Internet in the Albany Café Space. In order to study this the interviewer asked the participant to draw a sketch map indicating the extent of the wireless internet availability on a blank sheet of paper overlaid on a scaled plan drawing of the building. This was clarified as the shape on the plan which indicated the extents where it would still be possible to access the internet in the space, and that this would mean that any position outside their drawn shape would be somewhere where it would not be possible to log on. The interviewer pointed out key points on the building plan in order to orientate the participant and to make sure they understood the scale of the drawing. It was further explained that there was no right or wrong answer, and that anything they drew would be valid and useful for the study. The participant then proceeded to draw the sketch map, and when they had completed it, the interviewer thanked them and asked them some questions about what they had drawn to try to understand what they had represented, and how this also reflected on their behaviour in the space. The participant's verbal responses were also recorded and later transcribed.
Sample questions were:

How often do you use the Internet access?

How long do you tend to stay in the space?

Why do you come to the Albany to use the Internet?

Participants
Eleven people were interviewed for approximately fifteen to twenty minutes each. Participants participated voluntarily and were not paid. Participants were from a range of ages, genders and backgrounds. There were six male and five female participants.

Hypothesis
People have a poor perception of the visual and spatial presence of WiFi nodes. This will affect their behaviour and action in spaces where these technologies are present.

Environmental Setting
The study was conducted in the café space of the Albany Theatre, a community centre and theatre located in the heart of the Deptford area. The café space is indoors and situated close to the entrance to the building, and has an adjacent outdoor courtyard – see Fig 5.11 and Fig 5.12.

Fig 5.11 Café space – view towards 'serving area'

Fig 5.12 View towards entrance

The wireless network is available throughout the café space, but actually offers access to the internet in a wider area not confined to the physical walls and boundaries of the building, extending out into the street space to the front of the building and the courtyard. WiFi is a technology that can be limited by physical obstacles and materials, but this tends to only affect signal strength, rather than actually blocking the signal. In this manner the WiFi field is not bounded by the physical features or structure of a space. This is true for the boundaries between internal and external physical space, and other physical characteristics such as height.

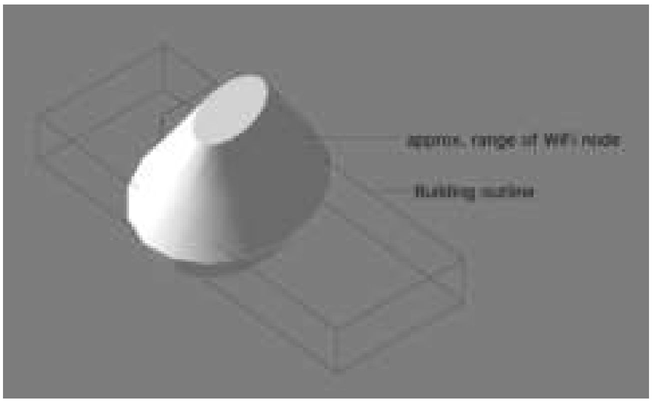


Fig 5.13 sketch visualisation of 3D spatial range of WiFi node

A WiFi signal extends in an elliptical three-dimensional form in all directions from the WiFi node, with the strength of the signal weakening in stages depending on distance from the node itself. The node at the Albany is approx. 200 square metres in area (approx 35 metres along the longest axis), and extends above floor level to a height of approx. 10 metres - see Fig 5.13 and Fig 5.14. The cross on the plan indicates the actual location of the node itself.

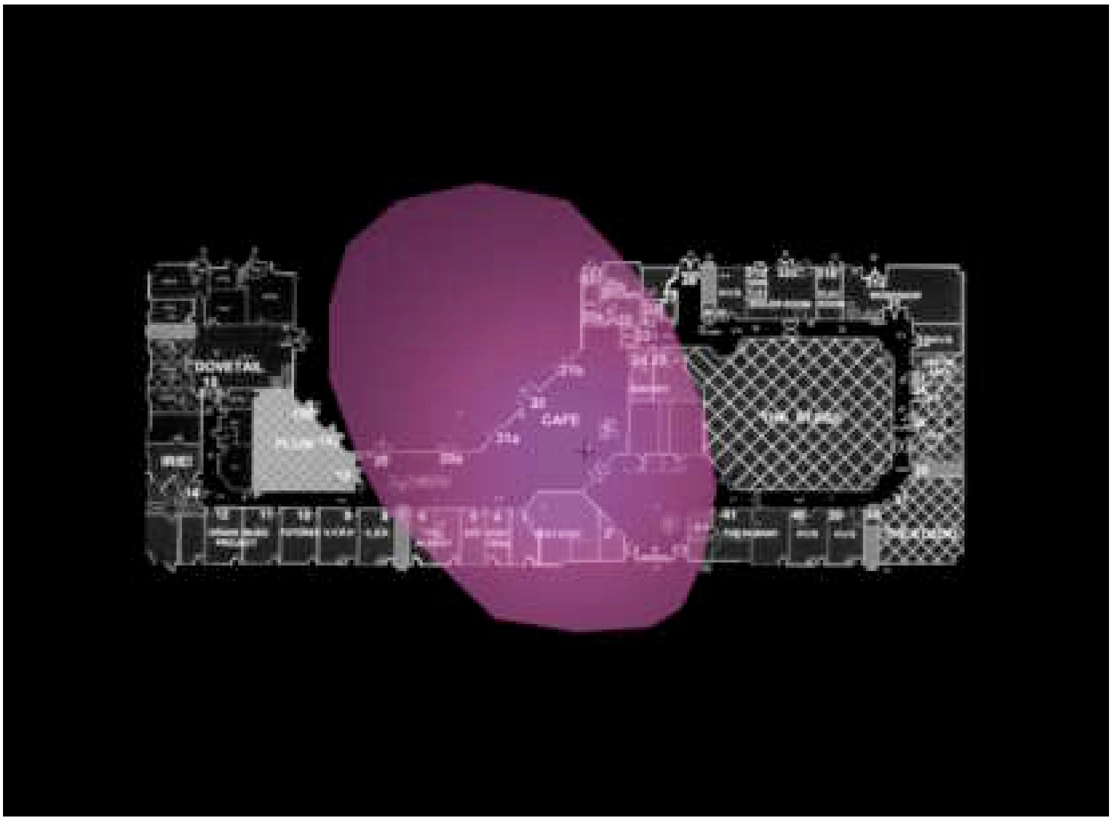


Fig 5.14 actual spatial presence of the public WiFi node (approximate)

5.3.3 Results

Results of Sketch Maps

The combined set of results for the eleven participants were incorporated into a single drawing to illustrate the range of responses and how they related to the space. The results (see Fig 5.15, for a full set of the maps drawn by participants is included in Appendix D-1) show the series of responses overlaid upon one another, and demonstrate that seven of the eleven participants conceived that the extent of the internet access was limited to the internal physical boundaries of the café space (i.e. the walls bounding the space). Two participants showed the access mostly confined to the internal space, but also showed 'patches' of access extending out into the courtyard space. Interestingly they tended to show the access and being linked to the courtyard space through physical access points; the doors opening out onto the space, which suggests that they thought the field somehow 'leaked out' through the doors. In this way they demonstrated clearly the fact that they perceived that the access or WiFi field was determined by the physical structure of the space. One participant didn't draw a shape at all, but instead indicated two lines along two sections of the wall space of the café, which they reported related to the places in which they had sat in the space and used the Internet.

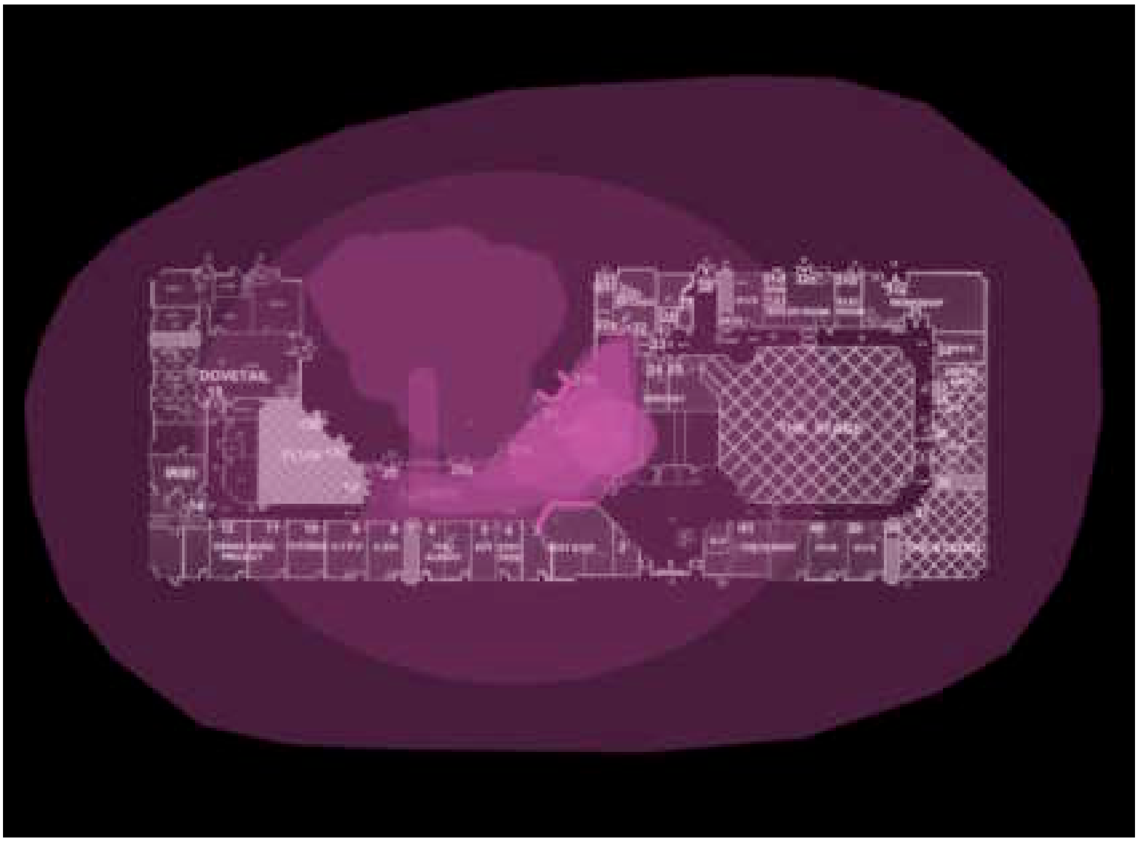


Fig 5.15 Results of participants' sketch maps of spatial presence of a public WiFi node (individual responses have been summarised and overlaid onto one image to enable comparison)

Only two participants indicated the actual condition that the wireless access extended to cover an area not confined to the physical boundaries of the space. They both drew elliptical shapes centred on the café space. There were no participants who accurately indicated the presence of the WiFi field in the space.

Results of Verbal Reports

Only two participants indicated that they were confident about the diagram they had drawn in terms of its accuracy. This positive self-report of knowledge did not reflect in the corresponding accuracy of one of these participants' sketch map, although the second participant did show some degree of accuracy in their sketch. Participants also responded that they found the purpose of the study unclear, in the sense that they had not thought about the WiFi having a spatial presence such that they had created a visual 'map in the head'. Instead they saw the space as having places where they could sit and access the Internet. For instance one participant reported:

'Well I know you can get access out in the foyer, but there's nowhere to sit out there so it's not usable'.

Other participants readily acknowledged that they didn't know where the wireless signal reached to and had simply based their perception on everyday experience, so that one person explained that:

'I know I can get it here because that's where I always sit, but I don't know about whether you can get access over there'

whereas another participant commented*:*

'You can maybe get access in the courtyard, but I've never tried'

Ten out of the eleven participants interviewed reported that they did not know where the WiFi router device was actually physically located in the space. The one person who was able to locate it fairly accurately was able to do so because they had been present on an occasion when it was moved from the ceiling space by the in-house technician.

5.3.4 Discussion

The study indicates that people have a poor understanding of how the wireless technology is present in the space in terms of its spatial extent. The technology was not perceived in terms of a visual image in the sense that it was represented as knowledge held in the form of a cognitive map. The key outcome was that they perceived the technology as having presence only where they could access it, or where it was usable. The presence was thus primarily linked to and dependent on the possibilities for certain types of behaviour in the space and not on the physical characteristics.

A second aspect of the usage of the wireless network in the Albany is that the flow of people through the space is slow. Instead of people spending a few minutes checking some piece of information online and then returning to a task in the local area the actual pattern of behaviour is almost the opposite. According to usage statistics from wireless traffic at the café [11], ninety percent of users are regular users making regular and often daily visits. In this way the space is not frequented by people dipping into the world of digital information before continuing on their journey, but rather as a work space or home-from-home offering the added benefit of the social interaction offered in a public space.

[11] Obtained during personal exchange with Stuart Calder, Events and Digital Technician, 1st October 2007

5.4 Phase 2: Locating the Wireless Network in Public Space

5.4.1 Introduction

The second stage of the study involved using a series of mapping techniques to establish the actual location and density of the pattern of wireless nodes. This seeks to establish if the way the nodes are located in urban space has any link with the spatial form and structure of the environment. Do the nodes afford certain types of spatial behaviour due to their location, and does this relate back to the existing behaviours associated with such spaces? For instance do open green spaces, traditionally places associated with leisure and relaxation also host nodes where people might choose to spend an hour surfing the Internet? Despite the ubiquity of such WiFi nodes in the environment there are surprisingly few resources available to people to identify the location of public WiFi nodes. An important factor to consider in studying the presence of such networks is the almost complete lack of any kind of overview mapping or viewable representation of the location and availability of these networks. Individual wireless access points are advertised locally at distinct locations, but the network of nodes is nowhere to be seen as a whole. In order to study the correlation between behaviour in public space as afforded by the physical properties of the space itself and the behaviour associated with the use of wireless internet it is first necessary to identify the location of the nodes within the space itself. It is then possible to discuss the patterns of use within the physical environment and those afforded by the wireless technology.

5.4.2 Method

Procedure

The detection process was carried out using a method known as wardriving. Wardriving is the practice of detecting and mapping wireless access points by driving through an area with specific equipment which logs data about wireless nodes. However in this study the WiFi nodes were also detected whilst walking around the area on foot, due to the number of pedestrianised areas, so as to ensure all accessible public space was mapped. The detection took place on three separate dates, and involved covering all public space in the defined area, either by driving or walking. The final data was combined so as to ensure that all available nodes were mapped. The equipment used to undertake this study was a Fujitsu-Siemens laptop PC with a Proxim Orinoco Gold Card connected to an external Antenna, and a Garmin E-trex GPS device – see Fig 5.16.

The PC was running a program called Netstumbler, which detects WiFi nodes and combines the data with the GPS location to provide a mapping of the Latitude and Longitude co-ordinates of a node together with other information such as signal strength, broadcast channel etc. See Fig 5.17 for a screen-grab. Once the data was recorded it was post-processed in a mapping software application, which translates the node name or SSID and GPS data onto a cartographic map.

Fig 5.16 Data gathering equipment

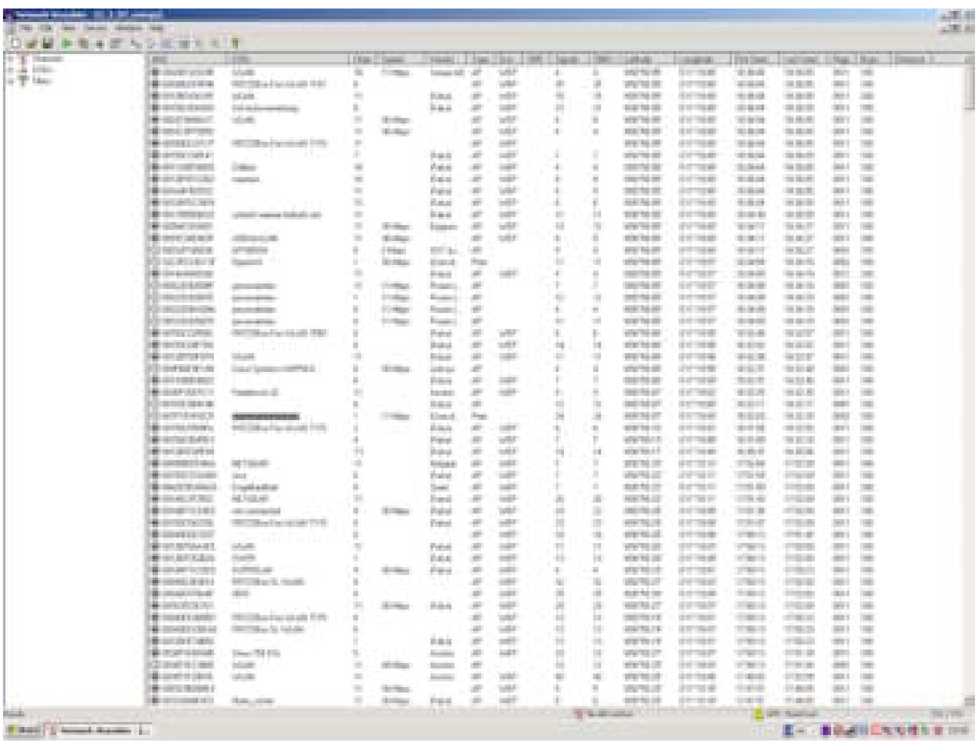


Fig 5.17 Netstumbler interface

Limitations of Study

There are a number of limitations with this technique regarding accuracy. The first limitation of the detection technique is that the nodes are recorded as being in the location where they are first detected, rather than identifying the true source of the signal. This means if a node is located inside a building, but the detection is undertaken in the street outside, then the node will be recorded as being located in the street. This appears to be an insurmountable flaw with such detection systems. Since WiFi routers are consumer technology and as such the devices are owned, controlled and administered by individuals this can only be overcome if owners of the WiFi nodes are encouraged to personally register the GPS location of a node in some form of public database. Otherwise there is no valid technical mechanism for a WiFi router to detect and record details about its own location; effectively a WiFi node will never know where it is unless some external system records this information and makes it public. A second consideration is the temporal nature of the technology. Depending on a whole number of conditions (such as weather, crowds, capacity) the signal strength and availability can vary widely. This is despite the fact that the black box emitting the wireless signal has not changed in any way. This means that a pattern of nodes detected on one day may differ from those detected on another day. For this reason the detection was undertaken on a series of three occasions to validate the data.

5.4.3 Results

The first outcome to note about the study is the large number of WiFi nodes detected. Over five hundred and eighty-nine public and encrypted nodes were found. The nodes were not spread evenly, but tended to show patterns of clustering based around building use. In the most densely covered locations, there was a density of up to one WiFi node per square metre (see Fig 5.18). Of this total of one hundred and nineteen nodes were public or open, or approximately twenty per cent of the total (see Fig 5.19). Thirty-one of the public nodes were those which were part of the Boundless wireless network and a further fourteen were sited in community centres or public amenities such as schools. The remaining seventy-four can be identified as nodes located in private residences which have been either deliberately or unknowingly left open by their owners.

This means that sixty per cent of the open nodes are not part of any organizational framework, and thus their availability can be considered as conditional on the control of individual persons who may or may not have altruistic intentions. Ten per cent of the public nodes are hosted by centres or organisations that already offer public physical space; theatres, arts organisations, visitor centres and even public houses.

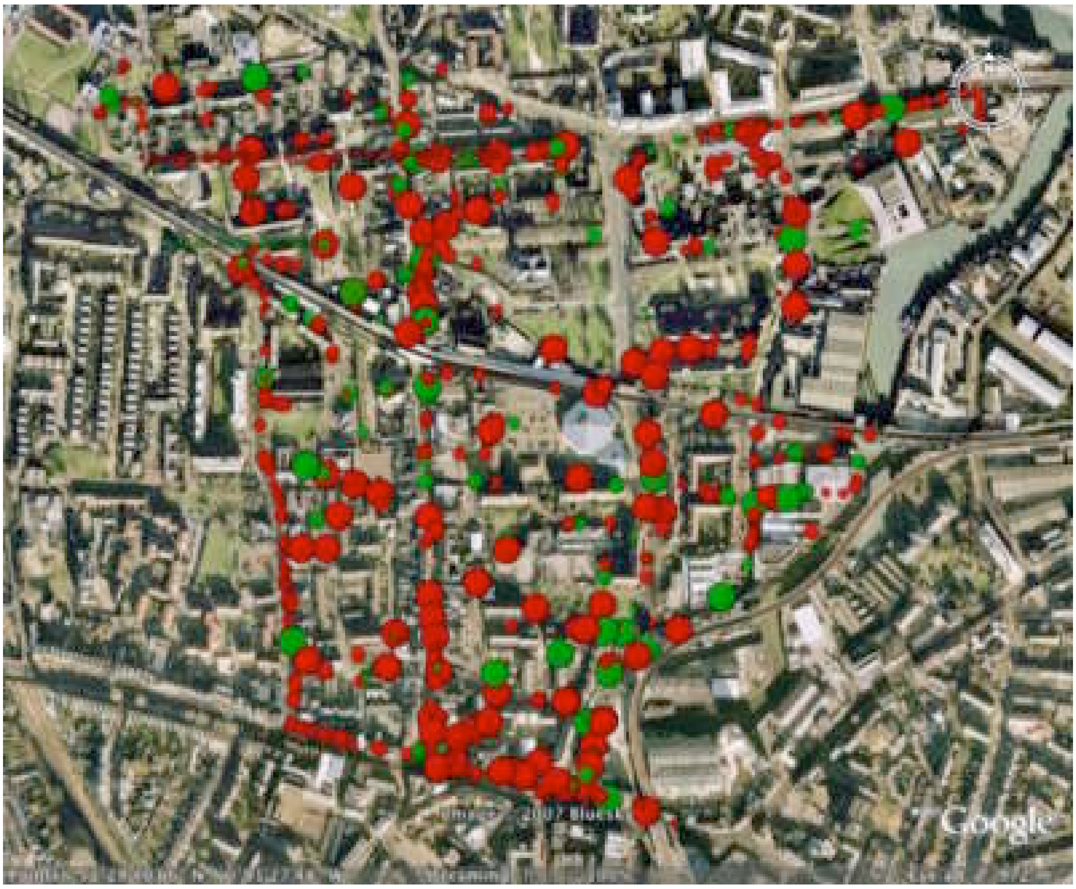


Fig 5.18 Density of public (green circles) and encrypted (red circles) WiFi nodes in neighbourhood

Importantly these nodes tend to be located in places where the facilities make it practically possible to access the Wi-Fi such as a warm place to sit and a power supply. They are also literally integrated into an existing social structure and physical location, with the associated guarantee of technical dependability and a degree of social interaction arising out of link to the relevant organization. In fact the key infrastructure is often the people, not the technology, a characteristic highlighted by James Stephens of the Boundless network:

We have a network of fifty nodes which link together and redistribute any broadband connectivity nodeholders have to offer. (Yet) it's the people who are most the important, and who require the most support, attention and encouragement. To establish a broad range of coverage in an area requires clear line of sight roof to roof connections but the ground level solutions are the hardest to co-ordinate and sustain' [12]

[12] Personal correspondence, 2 November 2007

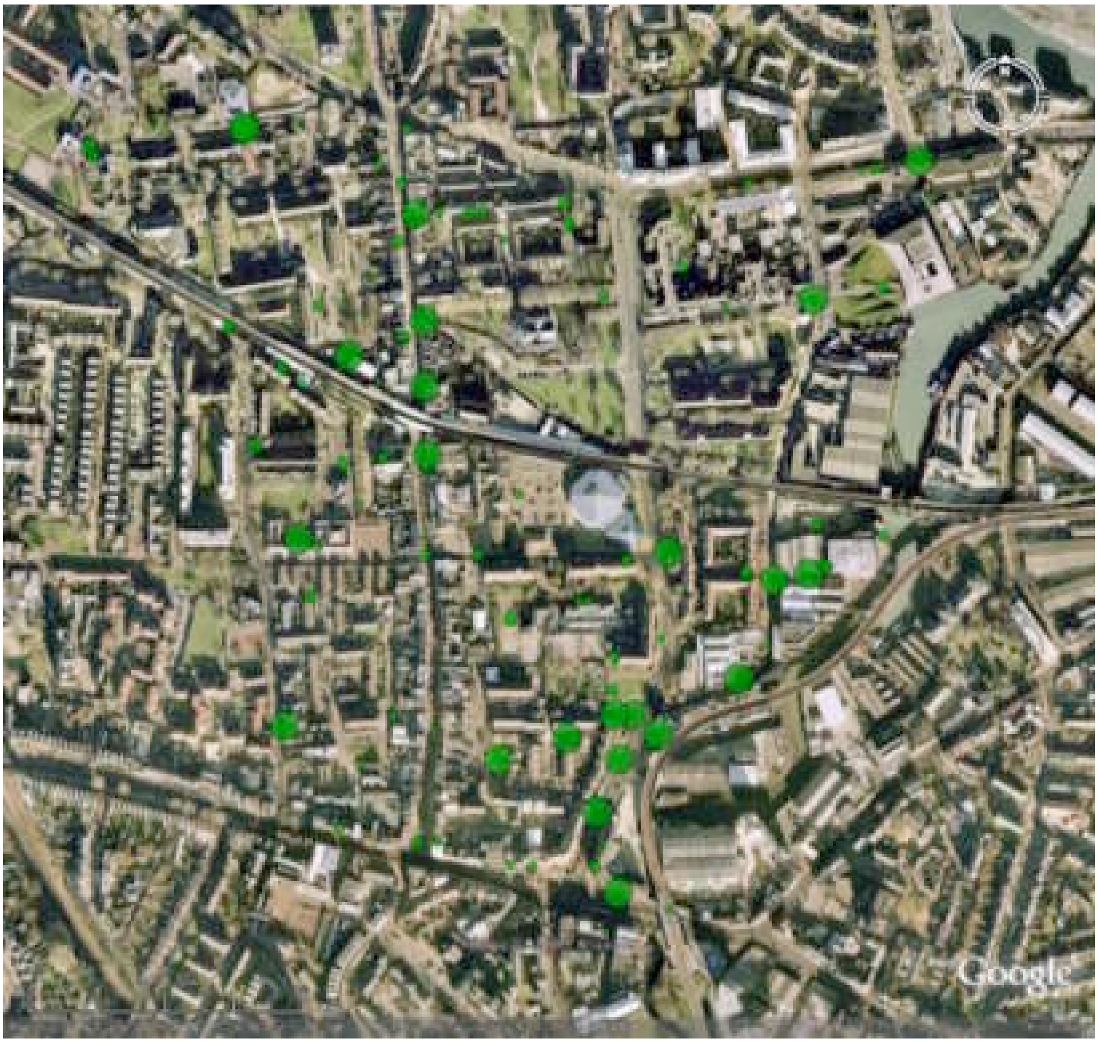


Fig 5.19 Density of public WiFi nodes in neighbourhood

Aside from these community nodes, the remaining public nodes are often located in private spaces such as homes or offices. The consequence of this is that although the WiFi access may spill out into open public space such as streets and parks, it is not primarily intended to be used in these locations. In fact one of the marked characteristics of the location of the nodes in this study is that none co-inside with any form of green open space. The traditional function of green open space as offering a place to spend spare time and for entertainment is thus never coincidental with the opportunity to access the wireless internet for leisure or relaxation purposes. Obviously this is not an intentional quality, but the location of the nodes means that WiFi access is often correlated with busy commercial and work-related public spaces.

For comparison purposes, the characteristics of the public space for the area studied are illustrated in Fig 5.20.

Key

- Streets, paths and pavements
- Green open spaces and parks
- Public buildings, community centres, schools and theatres
- Public open space (occupied by market stalls twice a week)

Fig 5.20 Analysis of public space

The main street running through the centre of the studied area is home to twelve (ten per cent of the total) of the public nodes, giving opportunities for the many shops along the street to link their commercial activities in physical space with online access. But there is not one example of crossover between these on and offline worlds either in the street space or any other site within the area studies. This highlights just one example of the predominant paradigm of the WiFi coverage in the area studied; that there is almost no meshing of the use and activities occurring in the urban public space and the corresponding location of public wireless access points. Aside from a comparatively small number of exceptions, the somewhat surprising outcome of this study is that the two worlds operate in almost independent spatial and social spaces.

5.5 Phase 3: Effect on Behaviour of the location of Public Wireless Nodes in Public Space

5.5.1 Introduction

This phase of the study investigates whether there is any link between the usage of public wireless nodes and the location of the nodes in relation to public space. In order to work within a defined community of practice the study focuses on the public WiFi nodes of the Boundless network located within the environmental setting. Usage statistics for individual nodes reveal patterns of behaviour, depending on time and volume of use are related back to the physical location of the node within its spatial and social setting. If individuals were conceptualising the nodes in terms of how they are located within a spatial setting it would be expected that patterns of behaviour would overlap between the technological spaces and the environment.

5.5.2 Method

Environmental Setting

The setting was the same as for Phase 2.

Procedure

Details of usage of the individual nodes was obtained for a typical two-day period at the beginning of October (Monday, Tuesday and Wednesday). This shows 'traffic' or usage of the wireless nodes by hour. It is captured through specialist software operating on the Boundless network called Locust World (see http://usa-manage4.locustworldlabs.net/login.php). This data was then correlated back to the physical location of the node to assess whether the position of the node and its relation to public space had any effect on the level of usage (see Fig 5.21).

There were two key types of analysis: times of usage and volume of usage. In studying times of usage it is intended to identify behaviour depending on whether the WiFi was accessed during 'public' hours (i.e. daytime) or at night, and also whether the patterns of access were consistent. The second analysis looks at overall volume of usage per node and patterns of data usage among users. This seeks to understand how popular nodes are and how this relates to their physical location. By studying patterns of usage it is proposed to assess whether the range of users is consistent or whether the data is distorted by individuals with high data volumes.

Fig 5.21 Position of Boundless nodes in relation to Public Space (for key to colour coding of map see Fig 5.20 above)

5.5.3 Results

Below is a summary of the usage of the seventeen wireless nodes illustrating times of usage with corresponding data volume (Table 5.1). The original graphs of usage for individual nodes can be found in Appendix D-2, and a typical graph is shown below (Fig 5.22).

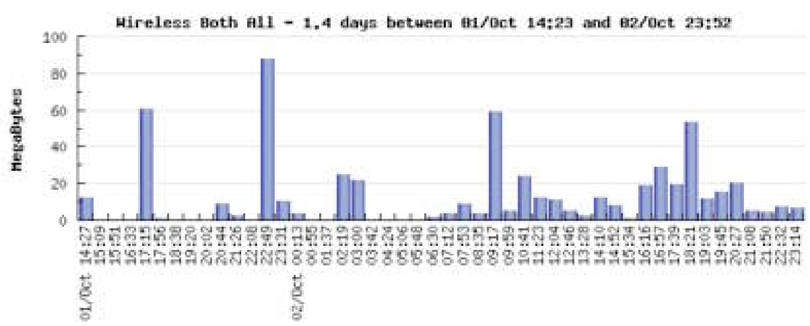


Fig 5.22 WiFi node ubiquity (Location: private residence, 86a Deptford High Street)

This shows that over a two-day period, the node was used fairly evenly throughout the daytime, with peaks in the evening.

WiFi node Name	Space Use	Summary
Amusement	Public housing estate	Very low usage during daytime
Beauty	Private low rise housing estate	Constant use throughout daytime, primarily afternoon
Belief	Public housing estate	Constant use throughout daytime running into late evening
Confidence	Private residential/shops	Use throughout daytime, but no consistent pattern
Continuity	Public housing estate	Constant use throughout daytime, primarily afternoon, but also peaks during middle of night
Cows	Small business centre	Use throughout daytime, mostly afternoon and also during middle of night, but no consistent pattern
Emotion	Laban Theatre	Sporadic use during daytime, higher nightime use
Game	Public House with community media centre above	Constant use throughout daytime and nighttime
Greed	Public housing estate	Primarily evening and nighttime usage
Invention	Public high-rise housing estate	Consistent usage during daytime, afternoon and early evening peaking between 16.00 and 23.00
Mudlarks	Creekside Community Wildlife Centre in Business park	Consistent but low use throughout daytime, high and sporadic evening usage and during nighttime
Reaction	Albany Theatre	Consistent but low use throughout daytime, high usage between 20.00 and 02.00
Reward	Private residential/high street shops	Sporadic low usage, primarily between 14.00 and 0.00
Strategy	Offices in Business park	Very low usage during daytime only
Treasure	Public House	Generally low usage, primarily in evening between 16.00 and 22.00
Ubiquity	High street shops/small businesses	Constant use throughout daytime, peaking in the afternoon

Table 5.1: Summary of timing of WiFi usage

The usage in official public buildings; the Albany Theatre, the Laban Theatre and Creekside Community Wildlife Centre suggests that the WiFi node may not be being accessed by visitors to the community centres as both Emotion (Laban) and Mudlarks (Creekside centre) have periods of high usage after 18.00 and often during the middle of the night. This does not show clearly in the 2 day data, but can be shown in the access information for a longer period of time – see Fig

5.23 and Fig 5.24. This suggests that either the WiFi node is being accessed by these in adjacent, non-public buildings, since these public buildings are closed at night.

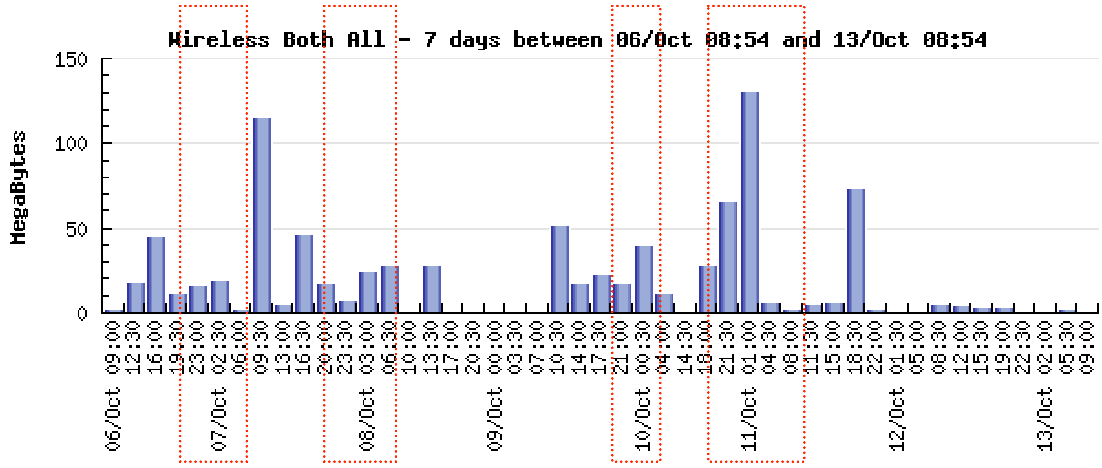


Fig 5.23 WiFi node Mudlarks- one weeks access

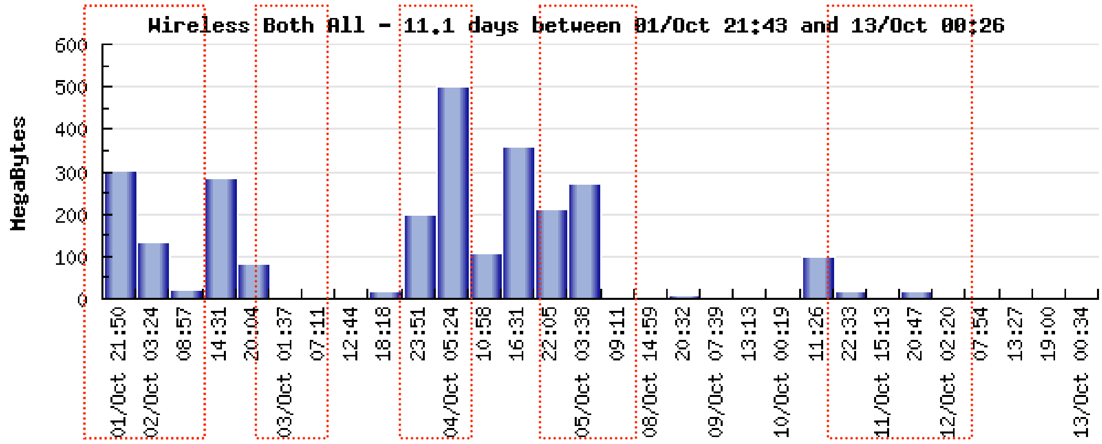


Fig 5.24 WiFi node emotion- two weeks access

In the previous study (see Section 5.7) WiFi access was analysed in the Albany Café, through their dedicated free WiFi node. During this study casual observation over three days noted approximately three or four users per day in the café space. Twelve out of thirteen of these users accessed the WiFi access offered by the Albany, which requires the user to logon, rather than the similarly available Boundless node (Reaction). This suggests either a lack of awareness of the boundless WiFi access or a trust issue, with the users extending their trust of the Albany centre and its facilities to the technical facilities such that they choose to use the Albany node whilst visiting the café space.

Clear patterns of consistent daytime usage can be seen for these WiFi nodes located in public housing (Beauty, Belief, Continuity, Invention). These nodes were also accessed during the early and late evening, suggesting a mix of users; some who are home during the day and some who use the Internet in the evening after work.

Quantity or Volume of Usage

Traffic statistics for the five highest users was gathered for the period corresponding to that shown in the graphs above (i.e. twenty-four hour period 1st/2nd/3rd October 2007) – refer to Appendix D-3 for a full set of data. A typical set of results for a single node is shown in Table 5.2 and the results for all the nodes are summarised in Table 5.3.

Ubiquity	
00:18:de:aa:fe:fe	186 mb
b2.c1.1343.static.theplanet.com.	56 mb
ip-72-55-140-12.static.privatedns.com.	37 mb
80.67.87.169	27 mb
195.8.214.6	16 mb

Table 5.2 Usage by data volume for WiFi node 'ubiquity'

WiFi node	**Space Use**	**Summary**
Amusement	Public housing estate	Very low usage
Beauty	Private low rise housing estate	High usage, with one user having very high usage
Belief	Public housing estate	High usage by one user, remainder fairly low.
Confidence	Private residential/shops	Low usage, with 3 of 5 users being minimal
Continuity	Public housing estate	Medium level usage,
Cows	Small business centre	Fairly high usage, with users evenly distributed
Emotion	Laban Theatre	Medium to low level usage fairly evenly distributed
Game	Public House with community media centre above	Medium level usage fairly evenly distributed
Greed	Public housing estate	Low level usage evenly distributed
Invention	Public high-rise housing estate	Medium usage evenly distributed
Mudlarks	Creekside Community Wildlife Centre in Business park	Medium to low level usage fairly evenly distributed
Reaction	Albany Theatre	Low level usage
Reward	Private residential/high street shops	Medium to low level usage fairly evenly distributed. The last user is a discussion forum
Strategy	Business park	Very low level usage
Treasure	Public House	Medium to low-level usage. The last user is a university webmail service in Holland
Ubiquity	High street shops/small businesses	Medium to low-level usage.

MAC IEEE OUI and Company ID Assignments. http://standards.ieee.org/regauth/oui/oui.txt, June 2006.

Table 5.3 Summary of patterns of usage by data volume for WiFi nodes

Generally no clear pattern emerges as to the types of location that encourage or enable constant Internet access to a range of users. However one feature is clear; wireless Internet through public nodes is not being accessed by people in open public space such as pedestrian areas, streets, parks etc. All access is confined to buildings; whether this be residential, public or commercial. High usage seems to occur in two building types; high-rise public housing (Belief, Continuity, Invention) and low-rise private residential areas (Beauty, Reward). This may be practically that the range of the wireless signal in such buildings literally reaches more people due to the density of the flats within a small area. There is also some consistent, but not as high volume, usage in Public Houses (Game, Treasure) which also operate to some extent as informal community centres. This indicates that people are using these venues as a 'home from home'; a comfortable and social place to check emails during the evening. However the official public buildings; the Albany Theatre, the Laban Theatre and Creekside Community Wildlife Centre do not have particularly high usage. Data volumes are however consistent and there appear to be a number of individual users who have similar patterns of use. There is generally low and inconsistent usage in commercial areas; business parks and shopping streets. This demonstrates that the key users are those based in often quite densely populated residential areas, with predominance in public housing. Typically residents in such high rise blocks come from lower income bands, and these patterns would suggest that sharing of a public WiFi node is perhaps motivated by economics and supported by the base of existing community ties within such housing blocks.

Node name	Top 5 node user's MAC Addresses		Manufacturer	Device Type
Amusement				
	00:11:f5:bc:29:9c	23 mb	Askey Computer Corp	Router
	00:0f:66:71:b5:8b	23 mb	Cisco-Linksys	Router
	00:19:db:04:43:4f	1 mb	Micro-star International Co., ltd.	Computer or Laptop
	00:0e:2e:a9:ba:62	1 mb	Edimax Technology Co., Ltd.	Wireless card for laptop or Computer
	00:19:7e:a8:06:7b	1 mb	Hon Hai Precision Ind. Co., Ltd	Computer or Laptop
Beauty				
	00:16:cf:8e:1c:cc	1.2 gb	Hon Hai Precision Ind. Co., Ltd	Computer or Laptop
	00:14:51:84:a2:ce	601 mb	Apple Computer Inc.	Computer or Laptop
	00:1c:b3:b4:7f:5d	238 mb	Apple Computer Inc	Computer or Laptop
	00:13:02:bb:d2:a8	208 mb	Intel Corporate	Computer or Laptop
	00:11:24:26:f4:c0	130 mb	Apple Computer	Computer or Laptop
Belief				
	00:19:7d:39:67:f3	789 mb	Hon Hai Precision Ind. Co., Ltd	Computer or Laptop
	cds227.lon.llnw.net.	53 mb	Server	
	89.202.193.167	33 mb	IP	
	cds258.lon.llnw.net.	32 mb	Server	
	ool182cdbc6.dyn.optonline.net.	32 mb	Server	

Cows				
	00:1b:63:05:0d:09	1004 mb	Apple Inc.	Computer or Laptop
	00:16:6f:8b:cd:db	695 mb	Intel Corporation	Computer or Laptop
	00:16:e3:d3:f3:fe	284 mb	Askey Computer Corp.	Router
	00:19:7d:6f:32:eb	167 mb	Hon Hai Precision Ind. Co., Ltd	Computer or Laptop
	00:12:bf:1a:6d:a5	161 mb	Arcadyan Technology Corporation	Wireless card for Computer or Laptop
confidence				
	00:19:d2:45:25:4f	20 mb	Intel Corporation	Computer or Laptop
	80.69.12.47	2 mb	IP	
	gayxxxparty.streamflex.com.	1 mb	Server	
	akamai-cluster.enta.net.	885 kb	Server	file streaming site
	66.151.149.78	842 kb	IP	
Continuity				
	00:90:4b:93:04:0b	157 mb	GemTek Technology Co., Ltd.	Router
	66.55.151.83	26 mb	IP	
	84.90.90.179	25 mb	IP	
	server3.profilepic.com.	18 mb	Server	flirting website
	18913102107.user.veloxzone.com.br.	18 mb	Server	file download site
Emotion				
	00:12:f0:a7:67:68	600 mb	Intel Corporate	Computer or Laptop
	85.17.190.4	109 mb	IP	
	cds258.lon.llnw.net	93 mb	Server	
	84.53.134.199	64 mb	IP	
	cds439.lon.llnw.net	63 mb	Server	
Game				
	00:30:65:09:96:04	66 mb	Apple Inc.	Computer or Laptop
	00:30:65:07:a0:b8	31 mb	Apple Inc.	Computer or Laptop
	00:17:3f:74:c5:37	21 mb	Belkin Corporation	Router
	00:16:cb:06:2f:b5	18 mb	Apple Computer	Computer or Laptop
	00:17:3f:c5:fe:4d	4 mb	Belkin Corporation	Router
Greed:				
	00:1b:63:0a:5f:5c	22 mb	Apple Inc.	Computer or Laptop
	00:13:ce:f0:d0:9e	6 mb	Intel Corporate	Computer or Laptop
	00:13:ce:54:9e:5f	1 mb	Intel Corporate	Computer or Laptop
	00:19:db:08:f7:05	864 kb	Microstar International Co., ltd.	Computer or Laptop
	00:90:4b:96:e9:64	573 kb	GemTek Technology Co., Ltd.	Router
Invention				
	00:90:4b:b9:48:b9	301 mb	GemTek Technology Co., Ltd.	Router
	00:0b:7d:17:58:89	223 mb	Solomon Extreme	??

			international ltd.	
	00:13:02:7b:23:03	196 mb	Intel Corporate	Computer or Laptop
	00:0e:2e:a9:ba:62	139 mb	Edimax Technology Co., Ltd.	Wireless card for laptop or Computer
	00:12:f0:9c:0f:ad	125 mb	Intel Corporate	Computer or Laptop
Mudlarks				
	00:11:24:27:e9:98	482 mb	Apple Computer	Computer or Laptop
	84-45-113-140.c4l.co.uk.	65 mb	Server	
	224.Red-81-34-134.dynamicIP.rima-tde.net.	31 mb	Server	
	static-108-70-7-89.ipcom.comunitel.net.	30 mb	Server	
	29-2-18-190.fibertel.com.ar.	29 mb	Server	
Reaction				
	00:0c:f6:25:df:12	20 mb	Sitecom Europe BV	Router-
	00:13:ce:6d:10:33	15 mb	Intel Corporate	Computer or Laptop-
	00:19:e3:02:dc:b9	9 mb	Apple mac	Computer or Laptop
	00:16:e3:d3:f3:fe	7 mb	Askey Computer Corp.	Router
	00:16:6f:87:f4:dd	3 mb	Intel Corporation	Computer or Laptop
Reward				
	00:19:7d:0d:f7:25	721 mb	Hon Hai Precision Ind. Co., Ltd	Computer or Laptop
	211.103.153.75	57 mb	IP	
	221.195.78.58	52 mb	IP	
	58.211.0.220	46 mb	IP	
	CPE001839e20e08-CM0014f859dfb2.cpe.net.cable.roger	33 mb	Server	
Strategy				
	00:19:e3:08:46:1f	58 kb	Apple mac	Computer or Laptop
	192.168.159.1	15 kb	IP	
	192.168.159.210	7 kb	IP	Server
	l1.login.vip.ukl.yahoo.com.	6 kb	Yahoo	Server
	84.53.134.208	5 kb	IP	Server
Treasure				
	00:0e:2e:39:19:70	340 mb	Edimax Technology Co., Ltd.	Wireless card for laptop or Computer
	87.79.33.12	70 mb	IP	
	63.210.156.201	57 mb	IP	
	8.2.32.86	22 mb	IP	
	x037056.its-s.tudelft.nl.	21 mb	Server	
Ubiquity				
	00:18:de:aa:fe:fe	186 mb	Intel Corporation	Computer or Laptop
	b2.c1.1343.static.the	56 mb	Server	administrator of

	planet.com.			a webserver
	ip-72-55-140-12.static.privatedns.com.	37 mb	IP	
	80.67.87.169	27 mb	IP	
	195.8.214.6	16 mb	IP	

N.B. Hon Hai Precision Ind. Co., Ltd manufactures computers for Apple, Intel, HP and Dell

Table 5.4: Summary of user device type and mobility

The data was taken for the top five users (by data volume) of each node, which does not reflect every user of the node, but gives a general overview of usage (see Table 5.4) The MAC[13] addresses were studied to classify the wireless NIC cards by manufacturer. Approximately 40% of users have devices with built-in wireless NICs, such as Intel (13.8%)[14], Apple (13.8%), unknown (either Apple, HP or Dell) (8.8%) and wireless cards (5%). The next group of users, 13.8%, use stand-alone wireless NICs such as GemTek (3.8%), Askey (3.8%), Belkin (2.5%), Sitecom (1.3%), Solomon (1.3%) and Linksys (1.3%) in their devices to access the boundless WiFi nodes. A further 22.5% of users accessed the interent through a direct IP and 20% through a direct server connection. This would suggest users were undertaking activities such as using ftp connections to download files, which tends to require more technical knowledge. In summary over half the users were accessing the internet directly from their laptop or computer, the remainder were more technically sophisticated users gaining an Internet connection through an IP or server connection.

It can be seen that these nodes are accessed exclusively by static users, there is no indication of any users 'roaming' or using more than one node. This can be elicited due to the fact there is no repetition of MAC Addresses at any of the nodes. Again this reinforces the conclusion that the majority of users are accessing the nodes from a fixed residential setting, and are not literally moving a laptop from one location to another during the course of their day. There is no indication that people accessing wireless networks do so in open public space, such as parks or streets. Generally the patterns reveal people who live in dense housing blocks, primarily public, take advantage of the free public Internet access available to them whilst they are at home. Public buildings offering indoor space to work were also not used to any great extent, and those working in office space which had similar densities of occupation, as the housing did not use the public WiFi access. Finally, there was no indication that people ever 'roamed' or were mobile whilst accessing the WiFi nodes. In this sense wireless Internet is perceived as a domestic and

[13] A MAC address is 6 bytes long with the first 3 bytes representing the manufacturer ID and the last 3 bytes representing the card ID. The manufacturer ID list from IEEE was used to classify the 6775 user NICs (IEEE OUI and Company ID Assignments. http://standards.ieee.org/regauth/oui/oui.txt, June 2006.)

[14] Note: Since early 2006 Intel processors have been installed as standard in the new generation of Apple laptops and computers. This means that some of the Intel devices may actually be Apple laptops.

static technology, and is not bringing people out of existing environments to access the Internet. However there are two aspects to take into consideration regarding the results discussed above. The first is the effect of the weather; the data was gathered in October, when it is traditionally cold and not suitable for remaining outdoors for long periods of time. It is just not practical or comfortable to work outside. Secondly, the local environment of Deptford is a poor inner-city area with its associated problems of street crime (in 2007, there were 127 reported robberies of a person in the Borough of Lewisham, of which Deptford forms a part - see http:// www.met.police.uk/ crimefigures/boroughs/pl_month%20-%20mps.htm). If an individual were to access the WiFi nodes using a laptop this would generally be perceived as risky, due the value of the laptop and the ease with which it could be stolen. These two factors alone would prohibit most people from choosing to access the wireless nodes in external public space. Despite this omnipresent fear of crime, mobile phones are ubiquitous in the neighbourhood. These devices are often expensive items in themselves, but are not perceived as necessarily susceptible to theft as more bulky technological items such as laptops. However if an individual did want to access the public inherent in a public building this study highlighted that where public buildings, all of which have safe, warm seating areas inside, offered WiFi availability they did not show high volumes of use during the daytime. Yet these spaces are well used in terms of those visiting the café spaces, educational resources and other such public facilities. Again there is little correspondence between the usage of public 'wireless space' offered by the wireless Internet and the physical 'public space'.

5.6 Discussion:

5.6.1 Conceptualisations of Space Embedded with Mobile and Wireless Technologies

The way in which we view public space it has a visible appearance with salient features that structure it; there are landmarks, visually familiar places, open viewpoints, and closed spaces. These visuo-spatial properties of public space enable and frame patterns of behaviour and activity. For example we tend to meet people at commonly recognizable landmarks; below a clock or on a street corner, and we relax in spaces, which often have a physical openness. But as demonstrated in the study of the perception of the spatial presence of a wireless node, wireless technologies are not visible structures in public space. The presence of networks in public space exists in a manner more similar to our concepts of a social network. Our notion of the social network of friends, relations and acquaintances exists as a highly developed framework in the mind of an individual, not as a visuospatial mental image, but instead as a network of possible relations connected through threads of weak and strong ties. Thus we see these technologies as connection points with opportunities for accessing information. A person is thus perceived as being separated from another only by a switch to a network connection, not by a physical distance in space.

The previously defined aspects of the 'real world' which can be exploited as part of a spatial model need to be informed by the affordances of mobile and wireless technologies. In order to reflect on some characteristics of space which are affected by the presence of these technologies it is useful to be able to define some specific spatial qualities. These qualities are not intended to provide a categorical definition, but rather to seek to refine some of the more general discussion about how space is affected by ubiquitous technologies (Willis 2008). To some extent they are a response and re-appraisal of Harrison's and Dourish's brief outline of the characteristics of 'hybrid space' (see Section 2.5.2) which they defined as '*relational orientation and reciprocity, proximity and action, and finally partitioning and presence and awareness'* in their 1998 paper 'Re-Placing Space' (Harrison & Dourish 1996 p. 68). Following from this, the concept of 'recipricocity' has been replaced with the concept of linkage (see below for a description), 'partitioning' has been reframed as bounded-ness, and Harrison and Dourish's concept of 'relational orientation' re-defined as separation. The quality of presence remains as described in the original concept, but it is extended to incorporate the importance of the visual experience of space, which we have proposed is no longer the defining nature of experience with technologies. Instead the experience of space is not about visual presence and recognition, but about awareness of the possibility to establish connections with other people or spaces, whether they are physically present or not. The final characteristic of temporality does not draw from the Harrison and Dourish paper, but is considered a fundamental quality in the experience of space with and through technology. A description of the qualities can be summarised as follows:

Separation

The concept of distance describes the state of two objects, which cannot by definition be physically present in the same location, and correspondingly that physical separation or absolute position is a key property of any person or thing. This can be extended towards the relational aspect of spatial proximity, where concepts of closeness and remoteness are grounded. However, displacement in layered media spaces is not confined to the physical properties of 'real world' objects, but also extends to include the specific ranges of technologies. For instance Bluetooth enables interaction within a radius of approx. ten metres, whereas WiFi nodes offer access within a range of up to one hundred meters. As such the definition of interaction in a space of communication flows is structured around spatial nodes of opportunity.

Linkage

The concept of linkage or relation is inherent in space. For example, an effect in space, such as light and shadow, is felt universally; light doesn't just fall on one side of an object, but illuminates all sides in a proportional manner. The concept of linkage in the use of technologies is intensified, and in many ways more subtle and differentiated levels of connectivity frame interaction. Action in network-type structures is characterised by a whole array of weak and strong links. Networked infrastructures start to dominate over physical spaces.

Bounded-ness

The idea that space has extents which are not infinite affects how structures of spatial separation and constraints are understood. Space is typically conceived as having some form of definable extent, which enables it to be sub-divided in a range of ways into units with particular properties. Out of such concepts arise sociological frameworks such as territory, neighbourhood and even personal space. In the interaction with technology, regions are not only defined by spatial extents, but also by patterns of informational or social access. Consequently, collectively defining boundaries becomes part of the pattern of communication; for example the common practice of asking for and reporting location at the beginning of a mobile phone call (Weilemann & Leuchovius 2005, Laurier 2001). Boundaries are still an omnipresent characteristic of space, but moving in and out of bounded zones can occur much like the flicking of a switch, rather than involving some form of graduated change.

Presence

If we take the case of individuals, then any experience of space is framed by a subjective awareness that they have a physical or bodily presence. In many cases this awareness is formed through perception, and vision tends to dominate. In the context of any activity this awareness is constantly measured, evaluated and updated, in processes such as orientation and navigation. Yet, technologies create a form of shared background space, not based on physical presence. Presence becomes more ambiguous, since previous reliance on the visual to orientate and structure awareness in space is augmented with non-visual presence in technological networked spaces. For instance, a form of co-location becomes possible, where interaction can occur in represented models of the 'real world', whilst simultaneously being physically present in the real world. One of the consequences of this is that actual physical co-presence; or the '*flesh meet'* (Ito et al. 2005 p.) is elevated to a higher level of importance.

Temporality

In three-dimensional space, time is seen as the fourth dimension. Space can simultaneously be understood as a fundamentally stable environment, undergoing little change (e.g. buildings), or conversely a changeful state in almost constant flux (e.g. a journey). However interactions with mobile and wireless technology occur in a 'real time', which is de-sequenced and person-centred rather than a global time. Stability and permanence are comprehended as particular qualities of the 'real world', and fluidity and change are valued. As such time becomes more malleable and capable of division into non-linear segments.

If we conceive of urban public space not just as a static construction but as a setting enacted by the patterns of behaviour of people moving within it, then the manner in which people's everyday practices are affected by their interaction with wireless technologies in effect transforms urban public space. Many have noted how the introduction of the mobile phone has changed the mobility patterns of users, so that rather than meeting at landmarks in public locations like plazas or street corners, and Townsend notes that young people tended to loosely co-ordinate movements and meetings through constant communication by mobile phone (Townsend 2000). The consequence of this is that '*un-tethered networks lead to a city coordinated on the fly in real time*' (Zook et al. 2004, p. 168). Increasingly wireless access from high-end mobile devices will start to change patterns of use, as these require less attention to the physical nature of the device, and are typically intended to be accessed for shorter periods. But even still the moment when an individual is required to pay attention to the device is a moment when their visual attention is concentrated on the device itself, and in most cases the individual will also voluntarily or involuntarily physically stop moving. All of these social and practical aspects of acting wirelessly tend to contrast against the idealised image of the person on the move, flicking between sets of information whilst walking through the city. In a sense what we have is a discord between the physical and social possibilities offered by wireless technologies and the reality of the physical and social world. The two domains are operating on different structures, layered one on top of another but in many instances not working as a unified domain. In order to resolve these disparities it will be necessary to rethink some of the ways we act, occupy and also construct our physical world.

5.7 Conclusion

In the empirical work undertaken the effect of wireless networks on perception of urban public space was studied. The investigation took place in a real-world setting, and involved using a range of methodologies to assess, investigate and evaluate the nature of perception and behaviour in spatial settings. The research identified that the non-visual presence of such networks mean that people tend not to perceive such technologies in spatial terms. Further, the complex and rich nature of social interaction in public space is transformed when these interactions are less defined by physical boundaries and frameworks. In this chapter a series of spatial concepts was defined, such as separation, bounded-ness, linkage, presence and temporality. It was claimed that these qualities are reconfigured by mobile and wireless technologies with the consequence that although the physical setting still influences our actions, many aspects of social connectedness are further elaborated and accentuated. If we see urban space not just as a static construction but as a setting enacted by the patterns of behaviour of people moving within it, then people's everyday practices are affected by their interaction with wireless technologies.

6

Evaluation of Empirical Work

6.1 Abstract and Introduction

In this chapter the outcomes from the empirical work are reviewed and drawn together to develop an appropriate theoretical and applied approach for responding to the specific issues identified. In studying the interactions between individuals, technology and the environment Chapter 4 focused on the interaction between mobile technologies and the individual. It then discussed the implications that this had for how knowledge about the environment was acquired. The key outcome was that when people interact with spatial information delivered on mobile technologies whilst moving through the environment they learn the environment in a fragmented manner, and their attention is divided between the demands of the technology and the task at hand. In Chapter 5 the focus shifted to the individual's interaction with the environment and the effect this has when it is embedded with technologies, on how these technologies are perceived and acted upon. It was found that there is a disparity between how people perceive and act in urban public space and when they interact with wireless technologies. The 'spaces' created by mobile and wireless technologies are creating different structures for both conceptualising and thus acting in the world, and on many levels these spaces fail to mesh with the physical spaces of the urban environment. The following chapter will seek to integrate these two sets of findings together to understand the full nature of the interaction, and will outline three fundamental frameworks which characterise wayfinding situations. In order to evaluate on the findings of the empirical work in detail the following chapter seeks to reflect and extend the results into a better informed framework for defining wayfinding situations. The chapter is divided into three sections, each of which focuses on an aspect affecting the wayfinding situations. This approach is not intended to break down the discussion of the situation into distinct factors, but instead to look at the problem from different perspectives, whilst acknowledging that these factors are highly inter-related and relational in nature. The first is that wayfinding situations are enacted rather than the results of interactions. The second quality is that wayfinding situations are usually guided by many local and background sources, and that in order for these to support the situation they should be underspecified rather than abstract and automated. The final characteristic is that wayfinding situations, and in particular those that involve the enactment of technologies, are framed by a rich mix of spatial and social factors.

6.2 Refining a Characterisation of Wayfinding Situations

6.2.1 Wayfinding Situations are Enacted

In Chapter 3 the approach to wayfinding situations was introduced based on the work of Suchman (Suchman 1987). The problem domain of wayfinding was positioned within the concept of 'situated actions', where human communication, instead of being structured by a set of pre-defined plans '*rather the organization of situated action is an emergent property of moment-by-moment* *interactions between actors, and between actors and the environments of their action'* (Suchman 1987 p. 179). In the empirical work undertaken there has been an attempt to understand more fully some aspects of the situation in which a wayfinder perceives and acts. A key common finding is that a wayfinder acts not so much based on a set of definable mental processes, which are affected by, if somewhat removed from, the changeful aspects of the setting in which they find themselves but instead in a much more relational manner. In this sense the wayfinding situation does not present itself as a set of decisions based around literally finding one's way from A to B, affected more or less by a series of factors, such as the layout of a path or the position of a landmark. It is in fact a much more complex process which can be said to be '*enacted*' (Varela et al. 1945), a term which acknowledges the co-creation of observer and observed through the construction of their relation. It does not exist a priori in some form of contained and constrained structure, and is instead constructed dependent on a whole range of changeable circumstances, most of which are local in relation and effect.

Thus in Chapter 4 it was found that manner in which the wayfinder interacted with the technological support did not just simply affect performance in a task, but instead changed the very nature of how they perceived and learned about the space. This was the basis for redefining the interaction model introduced in empirical study one (see section 4.2 of Chapter 4) from a focus on overview type approach to a process-based model (Fig 4.29 in Chapter 4). Thus the wayfinder's decisions are less affected by pre-existing features of the spatial setting and the task, and more by the manner in which they present themselves during a situation. This explains the strong effect of demands on attention on the construction of knowledge during a wayfinding task. The experiment compared two groups of wayfinders undertaking a learning task in the same environmental conditions with a similar visual format of information to guide them. However there were significant differences in the knowledge acquired, as a result of one wayfinder being distracted by information presented on a mobile device during the task. Thus it was predominantly the process through which the wayfinder enacted the information available to them from both the mobile map and the environmental setting, and not the format or structure of the information that affected the situation. This was similar to the results in Chapter 5, where the way in which technology was embedded in the spatial setting also resulted in the individuals constructing a different relationship between themselves and the possibilities offered by the space for moving and acting. A key finding from this experiment was that it was not the static visuo-spatial characteristics of the space which afforded different types of action, but instead how the possibilities for action in the space became interwoven with pre-existing knowledge and the everyday activities of the individual. However this also highlighted conflicts, and the experiment found that individuals are not necessarily able to resolve the different possibilities for acting offered by the spatial and social settings.

6.2.2 *Guidance in Wayfinding Situations Should be Local*

During the development of spatial knowledge cannot be considered as solely residing in the head of the individual, but instead is distributed across the individual and the situation as they interact. Thus our interactions in space are not just the result of immediately perceived reactions, but are framed by schema or internalised concepts based on existing knowledge. In this sense concepts of space are fundamentally framed in terms of the circumstances in which they occur. In Chapter 4 the way in which such schemas may structure spatial knowledge was described, and also the nature of such schemas as being themselves not fixed structures but flexible and often fragmented frameworks. In Chapter 5 the characteristics of such frameworks for perceiving space embedded with technologies was studied. This found that such schemas are not necessarily visual or 'map'-like in nature, but instead are structured around the opportunities for certain types of activity within the space. This questions some of the ways in which such schemas are considered as what Tversky terms *'spatial mental models'* (Tversky 1993). In particular in Chapter 4 the limitations of mobile maps to support the construction of stable and useful mental schema was identified. Similarly in Chapter 5 it was found that people perceived the properties of space not in visual terms but instead in terms of the possibilities for enabling and supporting social connections. Both these studies took place in settings which reflected real-world conditions, and as such they exposed some of the localised and unpredictable qualities of wayfinding situations. In looking at ways to support wayfinding situations it is critical for forms of guidance to complement, rather than conflict with, the way in which people frame their decisions.

In the first study the focus was on the use of mobile maps as forms of guidance for wayfinding in urban space. Mobile maps deliver information about the situation for the individual to refer to whilst they are moving and acting; as such they may be considered ad-hoc forms of information. In principle this way of delivering information relevant to the particular conditions in which the individual is acting should be beneficial. However it was found that the automated way the information was presented resulted in the individual becoming a passive receiver of information. One of the reasons for this is that the individual are not able to relate the way they are experiencing the situation with the manner and format in which information about the situation is presented to them. This is an example of what is often termed the 'mapping problem', a concept that was introduced in Chapter 4 as a basis of the research problem being addressed in this thesis. The maps we refer to in this context are a fundamental example of what Brown highlights is how '*spatial information presented in an abstract manner permits only a certain way of acting in the world*' (Brown et al. 2004, p.3). If maps are to reflect the situation in which they are used then they need to embody what Turnbull refers to as '*shared examples of practice, having a local, contingent character intimately tied to human purpose and action*' (Turnbull 1989 p. 237). Thus as an individual acts in the world they need information about the situation to guide them which they can then relate to their immediate experience. They also need to be able to affect the information presented to them so that it reflects their actual needs and the changing conditions of the situation as part of an ongoing process. For this to occur the guidance should not be abstract and automated in format, but instead under-specified i.e. it should allow for the individual to construct a relation between themselves and the situation. This requirement is also reflected in the second empirical study, where the inability for individuals to map the two sets of spaces; that of the physical spatial setting and that of the setting created by embedded mobile technologies meant that their behaviour was limited. Consequently individuals were not able to exploit the full potential of the space. In order for the situation to be enacted in a more fulfilling manner, the relations between the aspects of the situation need to be supported. Thus a person finding their way is better guided by information, which allows the individual to construct this relation. Or to return to Suchman '*the function of abstract representations is not to serve as specifications for the local interactions, but rather to orient or position us in a way that will allow us, through local interactions, to exploit some contingencies of our environment and avoid others'* (Suchman 1987, p. 188). On a practical level what can this mean?

Firstly the spatial setting needs to be embedded with cues that easily map across the digital space to the physical space. Currently the way such cues are represented means that it is often difficult to match features in digital space and those in physical space. Secondly the delivery of guided information should not be automated, but instead require the stimulus of the individual as and when they require guidance. Thirdly the form of information should not seek to display accuracy or finite values, but instead it should reveal the quality of the data, rather than focusing on quantitative values. Thus, for instance, GPS position needs to be able to show the level of accuracy of the measurement and presentation of any position in space as it changes over time (depending on a whole range of real-world conditions). This requires the individual to make a value judgment on their actual location and not the technology. Finally information should be presented in the manner of links or connection to other information, rather than as finite and distinct attributes. Thus location should be presented not as an abstract position in space, but instead as a set of possible links to other locations. By restructuring the relational quality of information the ability to provide guidance in wayfinding situations is enhanced and the individual is able to construct their own idea of how to act rather than accepting abstract and automated information.

6.2.3 Wayfinding Situations are Framed by a Rich Mix of Social and Spatial Factors

The experience of space as mediated by mobile and wireless technologies transcends concepts of metric physical space. Wayfinding is almost exclusively discussed and documented in terms of how an individual acts on representations of space to make decisions in an environmental setting, where the qualities of the setting are physical features and configurations. However the empirical study in Chapter 5 found that individuals see the possibilities of space not just in terms of physical configurations and features but also as frameworks for connecting within social networks. This gives new perspectives on how an individual can be considered as making wayfinding decisions in the context of a situation. Qualities such as presence, separation, bounded-ness, temporality and linkage transcend the definitions of metric or Euclidean space. We are not quite at the stage where a person can be in two places at once, which would establish a whole new way of understanding the problem domain of wayfinding. But mobile and wireless technologies afford what Ito refers to as '*techno-social situations*' (Ito et al. 2005, p. 272), where a person is able to occupy multiple social spaces simultaneously which brings into question how we orient ourselves and move from one situation to another. This finding was indirectly substantiated in empirical study one, in the sense that the schema of knowledge constructed whilst an individual interacted with a mobile map resulted in a substantially different concept of connectedness between locations. Instead of developing an overview of the environment the mobile map users seemed to have learned the space as a series of local links between features in the environmental setting (see Fig 4.28 in Chapter 4). Metric distance between these linked locations was poorly acquired, suggesting that the space was not so much viewed as a series of quantitative points in space organized in a measurable configuration and rather as series of more-or-less connected places.

In Chapter 5, it was found that the participants in a study of how perception of a café space is understood when individuals accessed the wireless network only found the physical qualities of the space important in the sense that they afforded certain types of social situations. As such space enacted through such technologies conforms to a different concept of bounded-ness. Instead some form of definable extent space is instead experienced more in terms of regions that are not only defined by spatial extents, but also by patterns of informational or social access. As such the definition of interaction in a space of communication flows is structured around spatial nodes of opportunity. But perhaps the key characteristic of such spaces is that the concept of linkage is intensified, and in many ways more subtle and differentiated levels of connectivity frame interaction. Mobile and wireless technologies typically operate in infrastructures where connections are characterised by a whole array of weak and strong links, rather than being defined by the nature of their direct physical proximity.

This also has implications for the way in which wayfinding is understood as being structured around concepts of space which are image-like or have visual characteristics. Features such as landmarks, which are seen as key building blocks of spatial knowledge, are primarily understood as having at least some aspect of salient visual form. In fact the saliency of such features and configurations are primarily understood as perceived within visuo-spatial frameworks. Such thinking provides the basis for the work of respected thinkers on wayfinding such as Lynch (Lynch 1960) and Arthur and Passini (Arthur & Passsini 1992) where direct visual stimulus and response to physical properties of space are given precedence and there is little consideration of the rich set of social aspects that influence perception and reality. For instance a wayfinder is typically considered to make decisions about where to go based on what is immediately visible to them in their physical environment together with knowledge from against an image-like overview of the space or cognitive map. These factors then affect their decisions based on a particular task.

Yet wayfinders make decisions in space based on making or breaking social connections; we often move from A to B to meet people whether they are friends or strangers. We also rely on people in space to guide us; we may gravitate to a particular setting not based on its visually prominent characteristics but simply because there is a gathering of people or conversely because there is the opportunity to be alone. In particular a key aspect of wayfinding that has not been studied to any extent in this research is that wayfinding is not an activity undertaken as an individualistic activity; we tend to make decisions in pairs and in groups about where to go. Thus the situation in which a wayfinder acts also includes other people, who may be involved in influencing the situation either directly or indirectly. One aspect of the social qualities of space that was identified through the second empirical study was the way that mobile and wireless technologies affect the degree to which a person engages with the social space. As a person navigates a space using a mobile device their attention is distracted from the immediate social situation, although they are physically still present in that space. They are in a sense present in a remote social setting, whilst simultaneously being present in another more immediate one. For instance if we become lost whilst exploring an unfamiliar area, we may automatically ring someone on a mobile phone or access an online map instead of simply asking someone present in the immediate social setting. This characteristic for multiple and often dissociated levels of presence in a wayfinding situation has significant implications for how a wayfinder acts in space based on its social affordances.

6.3 Definition of a Wayfinding Situation

Derived from the above characteristics a wayfinding situation can be defined as follows:

'A wayfinding situation is an enacted practice, framed by a rich mix of social and spatial factors, where an individual seeks to make sense of local information guided by a background of experience in order to move and act in a spatial setting.'

6.4 *Conclusion*

In this chapter an evaluation of the combined findings of the research was undertaken. This sought to establish a new framework for understanding the basic focus of the research; wayfinding situations. Three sets of findings were discussed; the first a redefinition of the wayfinding situations not as result of a set of interactions, but instead as a process of enacted practices. The second finding reviewed how wayfinding situations could best be guided when they are mediated through technologies. Here the importance of enabling individuals to construct a relational quality between the different aspects of the situation as they act in real-world settings. The final, and perhaps most critical, outcome of the review of the empirical work was that the social aspect of wayfinding situations is fundamental, and that this is characterised by ideas of how spaces are connected through social ties as well as the physical boundaries that frame situations. The chapter concluded with a definition of a wayfinding situation. These findings provide the basis for a more differentiated response to the original research problem identified in Chapter one of this thesis. It also establishes a revised theoretical framework as a result of the evaluation of the empirical findings and proposes a basis for responding to these in an applied manner in the final stage of this research.

7

Applying the Empirical Findings

7.1 Abstract

As a response to the various factors affecting orientation and learning in the spatial environment with mobile devices, a proposal for an application is outlined. The proposal intends to provide a way for delivering spatial information for those navigating a specific setting, so that it is meaningful and engaging for the individual. However it is not introduced as a total solution to the research problem identified in Chapter 1 of this research or as a definitive solution to the problems of supporting wayfinding situations. Instead the implementation stage of the research is intended as a suggestion of an alternative way of approaching the issues raised in the empirical investigation, and as such it is a strategy under development. Fundamental to this stage of the research is the understanding that new ways of thinking and approaching the dynamic and situated nature of wayfinding are required, that move beyond the delivery of abstract forms of spatial information and communication technologies dissociated from their settings. Consequently a series of conceptual design elements based on mobile technologies are proposed, rather than a closed and discrete system. This approach has been adopted with the intention that these elements will provide more opportunities for an individual to enact the technologies, rather than passively interact with them. The project takes the central area of the city of Weimar, Germany as real-world setting for a pilot project responding to a defined wayfinding scenario. The requirements of the particular proposed implementation are then defined through a series of semi-formal mapping and ethnographic studies. The features of a prototype are described, and the results of a pilot usability study are discussed. Finally the benefits and drawbacks of the proposed system are reviewed, and an outline for the further stages of research required are discussed.

7.2 Introduction: An Alternative Approach to Supporting Wayfinding Situations

'It's not down in any map; true places never are'
(Melville 1851, p. 54)

This stage of the research seeks to address an alternative approach to enabling interaction with spatial information delivered in urban space. Our daily experience of space is not global, but highly personalised and tightly interwoven with features of our social lives and dynamic factors such as time. Space is experienced and enacted not as an abstract quality but as practiced experience. In everyday life this manifests itself in a number of ways. For instance when we travel to a new or semi-familiar place often what we really want to learn about a place is local knowledge, such as the short cut, the best restaurant or the history of the neighbourhood. This information resides in people, as memories and knowledge, not in abstract sources of information. In order to tap into this resource of local knowledge about place it is critical to understand where such knowledge about a place resides.

In fact often the best way to find your way in an unfamiliar place is to ask someone. In asking a local about the place you're in, it creates a sense of shared experience. It bridges the gap between the image and lived experience. It creates a situation where knowledge which they have about the place can be shared and valued. In order to realize the value and deliverability of local information what is required is a way of gathering or stimulating the authoring of such local information in a publicly available format. Public distributed authoring is already a common way for people to share information, through formats such as blogs and photo sharing websites. But what is needed is to extend this approach to capturing and sharing local place information, which will require people to adjust their traditional views of spatial information as being created and delivered by experts. Spaces will be seen as useful, not based on functional qualities, but instead based on social recommendations whether these people are friends or strangers. Obviously out of these changed attitudes to authoring information, issues of privacy will come into play, as well as blurred distinctions between concepts of what constitutes public and private spaces. But the primary structural change in terms of how space is viewed is that it needs to be perceived not as static, metric and contained but instead narrative in form and constructed out of everyday practice.

7.3 Setting

"Where else can you find so many good things in one small spot?"
Goethe (attributed)

Fig 7.1. 3D model of Urban Setting

The setting chosen for the development of a wayfinding support is an approximately 1km central area of the city of Weimar, Germany. The setting was chosen for a number of reasons relevant to the requirements of the study. Firstly the town boasts a rich urban public space; the streets are primarily pedestrianised and the centre is focused around walking as a means of moving around. The centre of the city is also remarkably compact and dense in form, meaning that the development of a prototype system was manageable over a relatively small physical area. The city has a very high number of visitors, in particular people who visit the city for one day only. Statistically, this amounts to over 3 million day visitors per year, with a smaller number of 150,000 people who stay overnight. Of these visitors only 13% are foreign visitors[15]. This can be set against the actual resident population of the city which is around 60,000 people. In addition the town has a number of visitors as well as residents who stay for short periods of time (one to two years).

This means that the city presents a wayfinding problem in that so many people moving through the city are unfamiliar with the environment. Thirdly the town's national and international status as a historical tourist destination means that a great deal of information about the city is available for the visitor; maps, guides and other various sets of information about the space. The Weimar Tourist Office also runs a city guide service which is very well used, and the guides are offered in thirteen languages including German, English, French, Russian, Japanese and Czechoslovakian. Along with this available information exists a corresponding set of visitor expectations of how the city might be experienced as well a concepts of its visual presence. However this means that many people are familiar with the historical relevance of the various sites in the city, but have no knowledge of how these individuals sites exist in configuration.

As a social setting Weimar has a complex and fluctuating mix of long-term residents, semi-permanent residents (many students or academics at the educational institutions) and short-term visitors. Weimar has a long and illustrious cultural history which draws visitors to the city and more recently in 1999 was Cultural Capital of Europe. In the period from 1949 to 1990 Weimar was part of the GDR or East Germany. In terms of facilities the city centre has a theatre, four libraries, many schools, a university, a music institute, around ten museums, a castle, three churches and two large parks all within an area of approximately one square kilometre.

The pedestrianised centre of the city is host to many markets, both weekly and annual events such as the Zwiebelmarkt (see Fig 7.2). This aspect of the city acts as a rich urban public space, with lots of opportunity for social interaction.

[15] Personal conversation, Weimar Tourist Office, 20th January 2007

Fig 7.2 Street stand in central pedestrianised area of Weimar

In terms of technology the city is also host a public wireless network: 'wireless weimar' (see Fig 7.3 for a map of the locations of the nodes) which is a community run series of wireless nodes which aims to offer a free, independent and un-commercial internet access in the city (http://wireless.subsignal.org/index.php?title=Hauptseite). Weimar has all the usual embedded technological networks, such as mobile phone coverage etc.

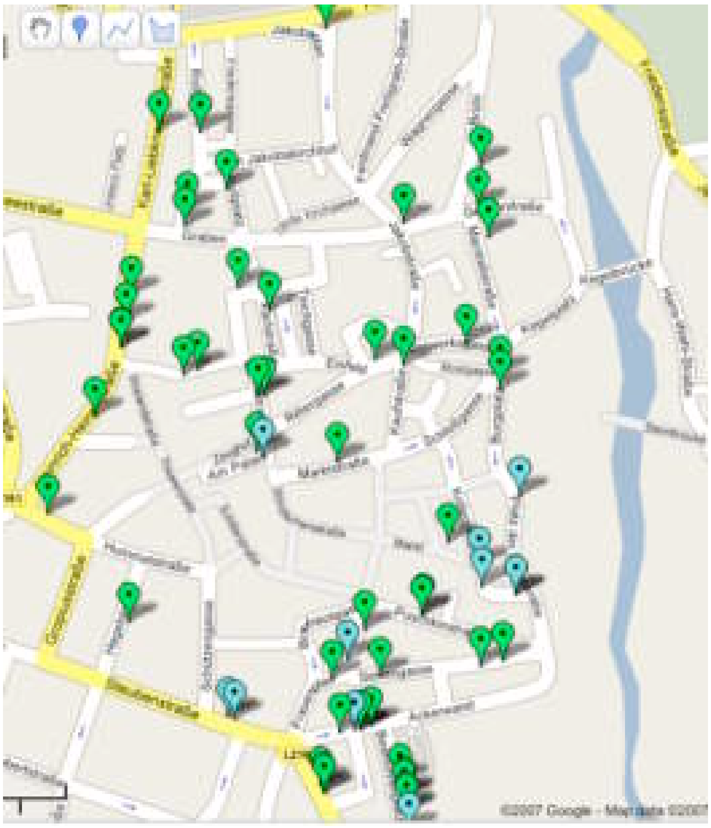


Fig 7.3 Location of public WiFi nodes

7.4 Scenario

A visitor to Weimar approaches the city with prior expectations and probably plans about how they will experience the city. Typically they will spend a relatively short period of time in the city itself, and may come away at the end of a trip without having engaged with the real city, its local residents and the everyday stories of the place. Instead they will have superficially touched the city in the role of a 'tourist'. They may also find that they are led or guided through the city for much of their trip, so that once they leave they would have had little chance to create their own memories. The relatively complex configuration of streets and paths through the city mean that often they will have remained on a limited set of routes through the urban space.

In order to create a different level of engagement, the scenario proposed is that at specific key points in the trip they will be able to interact with everyday stories and memories of the city as recorded by those who know it intimately. Since these stories are delivered only at the actual locations in the city which they relate to, then the visitor is encouraged to see the city through the eyes of the local, and to establish a connection to it through the narrative. As they listen to the story on a mobile device this helps to build up a memory for the place, and as they move through the city the accumulation of heard stories builds up a picture of the city which is embedded in these key nodal points. These nodal points are literally visible in the city as a series of illuminated posts, giving a visual and material indication of the source of the information that is being delivered. Once they have listened to a story they also have the opportunity to record their own story and to capture their own experience of the city, which is then added into the database available to other users of the system. Thus over time a body of stories embedded in key places in the city develops, creating a way for people to find their way through the city by engaging with the local knowledge of the urban space.

7.5 Requirements

Requirements for the system were developed through a series of site-specific empirical studies; firstly a sketch map study and secondly a semi-formal ethnographic study of wayfinding practices in the urban space.

7.5.1 Requirements Study One: Sketch Maps of Weimar Spatial Relationships

In order to understand the local spatial characteristics of the particular urban setting a sketch map study was undertaken. The intention was to identify how the city is experienced, not as a series of static physical spaces, but instead as an inter-linked set of spaces.

Method:

The study was undertaken by interviewing people familiar with the city centre i.e. locals. This follows a methodology used by Milgram as part of his wider study entitled 'Psychological maps of Paris' which sought to uncover the associational structures of the city (Milgram & Jodelet 1976). In the study undertaken in Weimar, participants were asked to draw a sketch map based on their current location with particular attention given to indicating the links to local places. Participants were not paid to participate, were interviewed in the environmental setting and were chosen if they had more than two years knowledge of the city. Participants were approached and asked to draw a sketch map of the local area, showing the streets and any locations they considered important. To provide a context, it was explained that they should draw the map as though they were explaining the local area to a person new to the area, and that there was no incorrect results. In particular they were asked to represent the connections between different locations or their relationship to one another. The study was limited in scope; it was semi–formal, not completed under rigorous conditions, but it was intended to gain informal insights into local's perception of the structure of the city.

Results:

Across the various locations, the sketch maps showed a pattern which indicated that the city structure was conceived in 'chunks' or areas which were salient in themselves but poorly connected to adjacent 'chunks'. Even locals very familiar with the city had problems making even simple street connections between one place and another. Strong connections were however identified between Theatre Platz and Markt, although participants often incorrectly drew or named these connections. Theater Platz, Goethe Platz and Markt were linked by all participants, although again the actual linking paths were often wrongly named or the spatial relationship was incorrectly drawn (see Fig 7.4 and Fig 7.5).

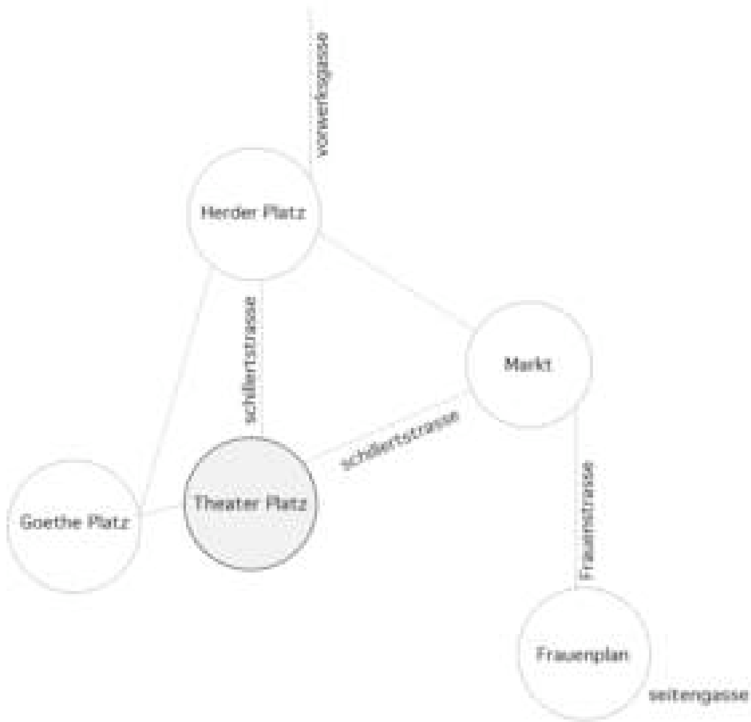


Fig 7.4: Associations to Theater Platz

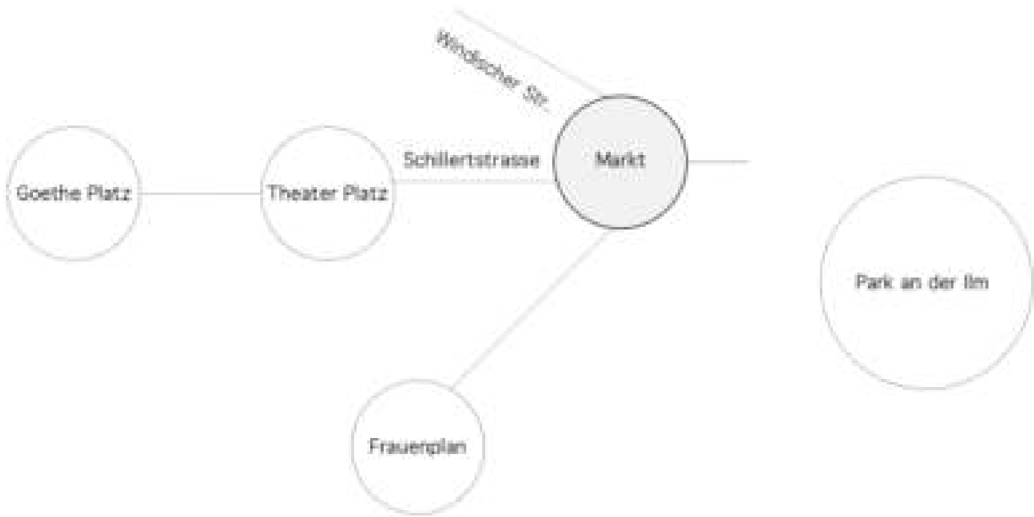


Fig 7.5: Associations to Markt

Based on an analysis of the connections made by the participants a 'chunking' map of Weimar, which summarised the areas and connections of the urban space – see Fig 7.6.

Fig 7.6: Chunking and Links in Urban Setting

7.5.2 Requirements study Two: Ethnographic Observational Study of Wayfinding Practices

In order to gain an understanding of how the city form of Weimar affects how people wayfind in the city an observational study was undertaken to record, document and analyse wayfinding practices.

Method

The study was undertaken over three days in spring 2007 in Weimar. It involved observing people in the act of finding their way and noting both where they paused to make decisions and what activities they undertook during the time in which they made decisions. The method was drawn from the ethnographic field work of Brown and Laurier, who have developed strategies for deriving field work from observation (Brown & Laurier 2004). Although in the study discussed here only visual data was recorded and there was no conversational analysis, as in the Brown & Laurier study. The people were not aware they were being observed, and as such they did not choose to ‘participate’ in the study. Wayfinders in the study were typically tourists, who were either referring to some form of map or a guidebook, through which they were identified. To document the wayfinding practices, photos were taken to document behaviour. However in order to authentically observe the practices every attempt was taken to undertake the study without disturbing the wayfinders or making them aware they were being observed.

Results

Again clear patterns emerged; this time in terms of wayfinding behaviour and at which particular points in the urban space in which they occurred. The first observation was that there were key 'nodes' in the environment where people paused, reviewed and acted. These are summarized in the Fig 7.7 below.

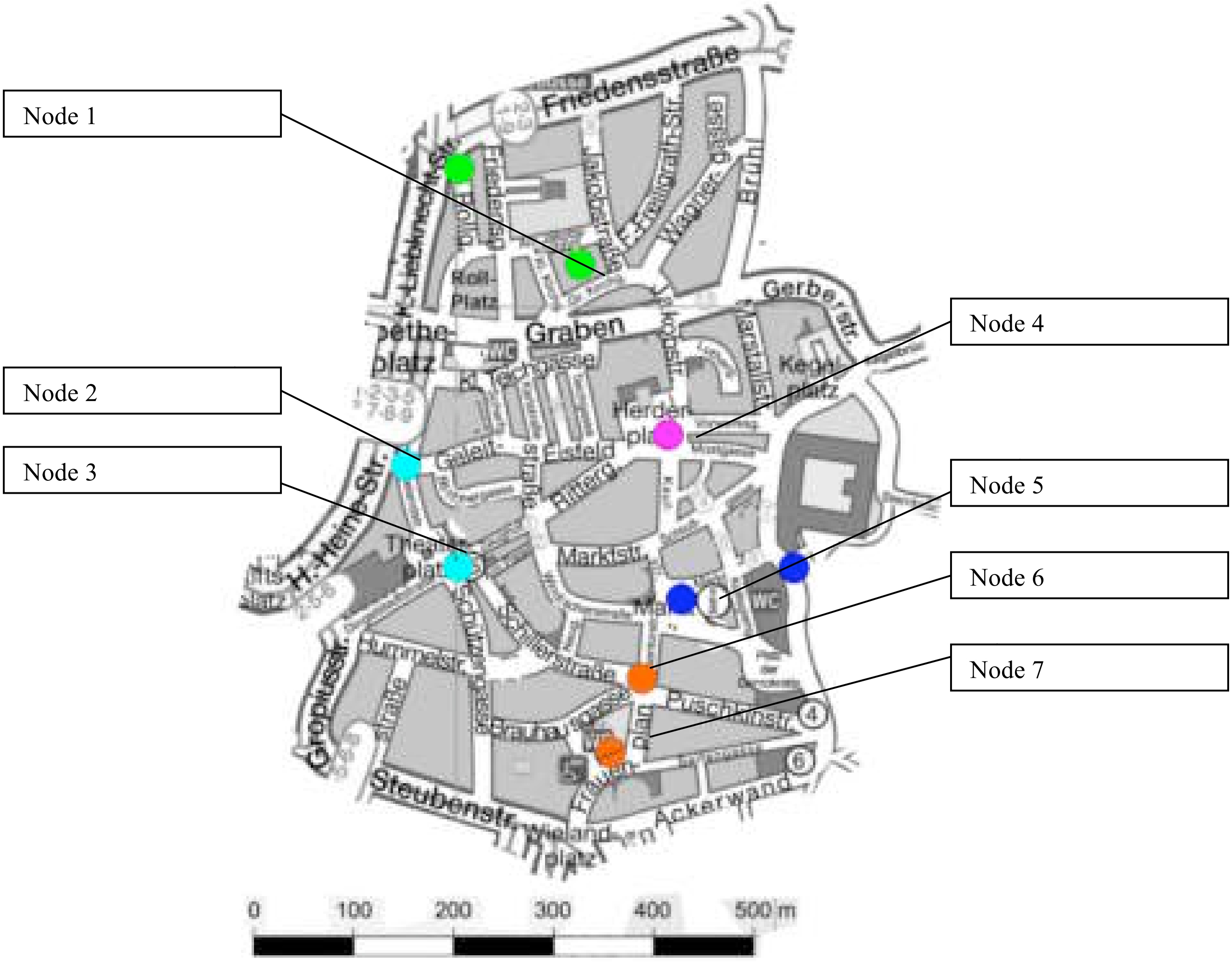


Fig 7.7 Nodes in the urban setting.

Fig 7.8 Node 1 Herderplatz

Fig 7.9 Node 2 Goetheplatz

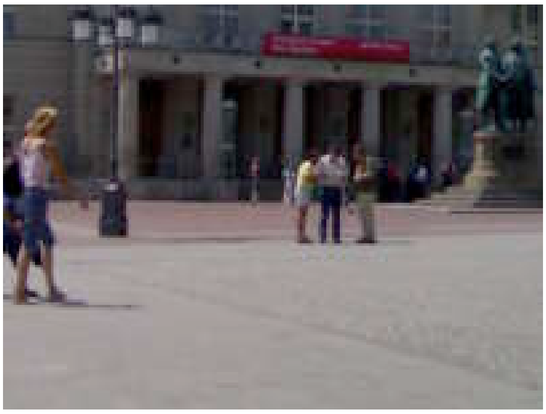


Fig 7.10 Node 3 Theaterplatz

Fig 7.11 Node 5 Marktplatz

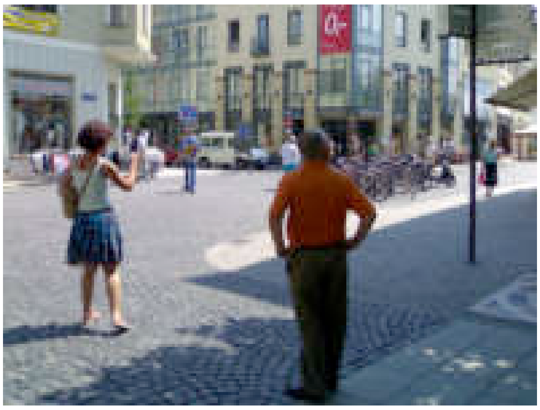


Fig 7.12 Node 6 Schillerstrasse

These decision point nodes corresponded closely with the 'chunks' identified in the study described above (see Fig 7.8 to Fig 7.12). A key characteristic of these nodes was that they occurred at physical boundaries; such as a T-Junction, a line in the road, or a corner. On further analysis of the combination of points it also emerged that these points all had visual sightlines leading from them, which enable people to reference their position and to orientate themselves. These nodes provided a basis for a whole range of decision making activities; quickly deciding where to go next, referencing a location in the real-world with that on a map, a photo opportunity, a place suitable for a longer pause (e.g. sitting down on a bench) and also as a meeting place. Arising out of this it is clear that to interact with information in an environment the individual needs to 'pause' to take time to reflect, plan and decide what to do next. It was also clear that the environmental structure itself provided a form of decision making structure which the wayfinder used to support a mapping of information in their head and that in the immediate environment. In this way the environment acts to support learning, and to enable the wayfinder to cross-reference and check against some form of plan. These nodes became part of a wayfinding situation; it created a structure or frame for moving between one set of decisions to the next. Thus the situations were fluid in themselves, but there were transitions between them, which corresponded with salient transition points in the urban setting.

7.6 Conceptual Design

The proposal is a series of interface elements which enables technologies to be implemented in the city so that people are encouraged to cross over from concentrating on the information delivered by the interface of the device and instead engage with local knowledge of the city. They seek to establish ways in which visitors or locals to a place can exchange knowledge and so create meaning about the place. The broader intention of proposing such a system is that it will facilitate learning of the spatial setting. The conceptual design provides a direct response to the issues identified in the empirical fieldwork in the previous chapters, and the requirements study described above.

Wayfinding Situation

7.6.1 Issue 1. Fragmentation of attention

The delivery of the information is not automated but depends on the user to some extent defining the nature of the wayfinding situation before seeking a response from the technological tool. This is implemented with the intention of allowing the individual to enact the aspect of the wayfinding situation which they are best able to; defining the significant information they need in the context of their actual needs. Correspondingly it enables the technological tool to be enacted in its optimal implementation; the computation of complex sets of spatial information into an easily understandable format.

Conceptual design response: The fundamental structure of the implementation of the system is that it is not a closed application but instead a series of independent tools where the individual is required to make choices about when and where to access the information.

7.6.2 Issue 2. Passive interaction

A further benefit of a system that comprises elements rather than a closed structure is that the individual is not required to be constantly interacting with the interface, but instead is motivated to interact with the information when they require assistance. This means that they are able to respond more directly with all the aspects of the real-world setting that help guide them; environmental features, immediate dynamic changes in the environment, social aspects and any other relevant background knowledge.

Conceptual design response: The application also offers a tool which provides support when the individual becomes disorientated or lost i.e. when they temporarily lose the ability to relate their own immediate location within the wider urban spatial configuration.

Implementation: whereami?

Fig 7.13 sketch of 'wherami' interface element

The device should not be constantly delivering information, but only provide location on demand. The 'wherami' mode is a function where the individual becomes disorientated in the environment to the point where they cannot localise themselves (see Fig 7.13). The 'wherami' button uses GPS to show a user's location on a map-like representation. The map representation is divided into 'districts' or chunks, so the user's location is only displayed in relation to the localised 'district'.

7.6.3 Issue 3. Unstable spatial mental model

The individual should be able to have access to an overview of possible options available to them, so that they can build up a strong and consistent idea of the structure of the environment. Since mobile devices support the retention of spatial features based on their interconnected aspects, then the information delivered should support this process by showing links between places rather than bounded areas. The information in the environment should not be provided in an exocentric map-like format, but instead as egocentric and schematised so that the individual is not overwhelmed with the quantity of information.

Conceptual design response: In addition to the way information is delivered at salient points in the environment, so that it becomes mentally associated and referenced with the setting, the individual should be able to build up their own narrative of the city.

Implementation: digital signpost

Fig 7.14 sketch of ‘digital signpost’ interface element

Fig This interface does not show a map-like representation, but rather a selection of possible destinations available from the users current location (see Fig 7.14). Destinations are shown in terms of direction and relation to the current location, but not as distinct points.

7.6.4 Issue 4. Lack of referencing between information delivered by application and social and spatial aspects of the real environment

A key feature of the type of information delivered by the tool is that it should not be global and abstract, but instead be ‘woven’ into the locality of the spatial setting, including its social and cultural qualities.

Conceptual design response: Information is embedded at the decision points within the setting, and is delivered in localised chunks based on proximity. Once the individual moves beyond the particular local chunk access the information is lost, unless the individual has interacted with it and saved it to memory. Additionally the form of the information should not be visual and abstract, but such that the individual interacts with people in the social space.

Implementation: Storypost

Storypost is an element which seeks to enable the delivery of local narrative-based technologies, and so assist wayfinding and discovery of local places. At key nodes in the city of Weimar illuminated posts will be located (see Fig 7.15). These posts metaphorically host stories about the place. The Storypost is a physical metal post with an illuminated top section installed in the street in the city of Weimar. Hidden inside the base of the post will be the Bluetooth marketing system, with power supply and a WiFi connection to a remotely located server/PC controlling the delivery and reception of messages.

Fig 7.15 Sketch of Storypost interface element

The name Storypost takes inspiration from an infrastructure in UK where physical markers have been placed at key points throughout the land to act as datum points for the Ordnance Survey mapping system. This network of pillars and benchmarks are called 'trigpoints' and were created in the 1930's as a tool to give surveyors a frame of reference for surveying the UK, in the days before electronic positioning aids such as GPS were available. There are 6,550 trigpoints in UK (a map of their distribution can be found at the trigpointing website) – see Fig 7.16 and Fig 7.17. Each one has a unique number which can be found on a plaque attached to the base of the trigpoint.

Fig 7.16 Trigpoint concrete pillar in open country (usually located at topographical high points so that one trigpoint can literally be seen from the next)

Fig 7.17 Trigpoint Benchmark, installed at 1 mile intervals between trigpoints

Thus these physical elements distributed throughout UK act as a way of binding the abstract world of mapping to the physical world; they create a literal reference between the two ways of perceiving and enacting space; one the world of maps and the other the world of lived experience.

Storypost seeks to create a similar series of datum points for intertwining the physical space of the city with the digital space of mobile and wireless technology. They seek to create a way of referencing between the two largely unconnected spaces. However instead of being placed at physical high points in the landscape they are instead located at nodal decision points in a wayfinding scenario. Thus they become a way of embedding a decision in a wayfinders task with the technological level of support that may assist them in this task. Similar to the trigpoints each Storypost is distinct from the next as distinguished by its unique location, although it might visibly seem similar to others in the network.

7.7 Explorative Prototype

It is anticipated that a system to support wayfinding situations would include all the elements described above. However for the purposes of this study one element of the proposal was developed to prototype stage; signpost.

The basic features of the Storypost application are as follows:
Listen and Receive: People in the zone of the Bluetooth Storypost receive a Bluetooth message with the text 'do you want to hear a story about this place?'. If the person accepts, an audio file from the selection in the database is randomly selected and sent via Bluetooth to the person's mobile. They then open the audio file and listen to the story.
Speak and Send: People record with their own voice a short audio on their mobile phone describing an event or feature of the place that is important to them. They then send this audio

file via Bluetooth to the Storypost. The stories are stored in order of being received. The database can only hold 10 stories at a time in the prototype phase.
Creating a Loop: The narrative loop can then continue if the listener chooses to record their own story about the place and sends it back to the post.

7.8 Prototype Development

A prototype was developed based on the features above. In order to put together a working model both the content and technical side of the application had to undergo development:

Content development
The key issue was that since the prototype was not publically available it was necessary to adopt another method for the gathering of local stories in order to have some initial content to test. This involved recording people narrating verbal memories or anecdotes about places identified in the 'node' study. The gathering of content was started with the location 'Markt' , and initially people were randomly approached and asked to participate in the gathering of verbal stories about the place. However it was found that this method of approaching people was not successful; the purpose of the study was not understood, and people did not appreciate how they could contribute. It appeared that people did not feel that their individual opinion or experience mattered, and many suggested that an expert or knowledgeable person would be more appropriate to make such a contribution. Additionally people felt 'put on the spot' in that they could not simply recount a story from memory about the place without having had some time to reflect and consider what was important to them, or what might be interesting to others. Consequently a different approach was adopted where it was decided to approach people who had some experience of telling stories about Weimar, or had some clear role as a 'holder' of information about the city either as a city official or some other position that gave them a 'right' to give their opinion. In the first case this involved approaching people who acted as tour guides for the city, since they had experience of narrating stories about place and also had a great deal of knowledge about the city. They were asked to participate in the study in advance, were given an explanation of the purpose of the project and provided with some background information. It was explained that what was required was not the recounting of historical facts about the place, but instead personal or everyday stories about specific points in the city. Once the project had been introduced to them they were given time, between a day and a week, to reflect on what might be suitable and then it was arranged to meet with them in the particular location to record their narrative. Technically the recordings were made using a Sony Minidisc player with Sennheiser MD22 microphone, which provided excellent voice recording quality. Recorded narratives were transferred to MP3 digital format. It was considered important that the narrative be recorded in the respective location, and at the beginning of each recording they were asked to give their name, the date and the place in which they stood. Parallel to these sessions, a series of

recordings were made during key events in the city; most notably the Christmas Market. The intention with this was that temporal events be captured, as these had their own quality of locality. Initially approximately five stories were captured for three of the location nodes (refer to Fig 7.7 for location of nodes):

Location	Story theme/author	Summary
Node: Markt	Baum an Weihnachtsmark/ Matthias Legler	The story and history of the Christmas Market from the organiser
	Zwiebelmarkt/Jutta Schulze	A personal memory of the Zwiebelmarkt over the years and how it has changed
	Shop on Markt/Noriko Kimura	A personal memory of a shop on the corner of Markt where the narrator (a musician) bought her first piece of music
	Elephant Hotel/ Dieter Kunkel	A story about the hotel, and how it was once host to the German singer Udo Lindenberg
	Weihnachtsmarktlied/ Dieter Kunkel	A story of the origins of the Weimar Christmas song
	Lily Palma/ Jutte Schulze	A personal story about sneaking out of school to see Lily Palma during a film recording at the Hotel Elephant
	Markt/ Jutte Schulze	A memory of Markt in DDR times
Node: Theaterplatz/Goetheplatz	Description of the inside of the theatre/ Noriko Kimura	A personal description of the feel of the inside of the theatre from someone who has performed there numerous times
	Memory of a theatre trip/Jutta Schulze	A memory of a trip to the theatre when she was a child
	Story of the theatre/ Dieter Kunkel	A memory of a public reaction to the fact that many people left Weimar when the DDR times came to an end
	Story of Russischer Hof Hotel/Jutta Schulze	A story of the changes to Goetheplatz over the last twenty years
Node:Rollplatz/St Jakobskirche	Memory of performance/ Noriko Kimura	A personal memory of a performance in the church
	Story of renovations of church/Herr Scheider	A story about the various interesting objects found underneath the floor and in the walls during the renovation of church, told by the caretaker
	Song/ Noriko Kimura	A favourite song performed by a professional opera singer and recorded in the church space
	Story of the protection of the tombs of Goethe and Schiller/ Herr Scheider	A personal interpretation of a story about the protection of the tombs during the 2nd World War by a local woman, and the danger this caused for her, told by the caretaker

Table 6.1: Summary of recorded stories

A further stage in the gathering of local stories about the place was access to the City archive. The archives for the specific locations were studied for newspaper stories or descriptions of everyday events.

Problems identified: One key issue identified with the gathering of stories was that of language. Since local knowledge is held by German speakers, and the stories were recorded as verbal narratives the language of the recording was German. However it is anticipated that many of those that will use the system will have English as their chosen language. This highlights a problem that exists at the very heart of exchange of information between locals and strangers in the city; that of the language barrier.

Technical development

In the prototype stage it was decided to focus on the sending of stories to people in specific locations, and not to include the facility of the people responding by recording their own stories and adding them to the database. The model of the system is as follows:

- Bluetooth sender (running on laptop computer embedded in location)
- Mobile phone with Bluetooth switched on (property of participant and no special application required to be installed on the device)
- Internet site with content uploaded as mp3 files (www.storypost.de)
- Public WiFi node

The system works by integrating the delivery of a Bluetooth message with a hyperlink to a website, where the content is accessible. Thus as a person passes within the proximity of a node; approximately 15 metre radius, they receive a message via Bluetooth. The message reads as follows:

'Do you want to receive a message from storypost' (see Fig 7.18 below)

Fig 7.18 Mobile phone screenshot of initial contact message

This is a default message inherent in the Bluetooth system, where the receiver has to actively accept a message. Once they accept the message they receive the following information as a text message:
'Do you want to hear a story about this place: http://www.storypost.de' (see Fig 7.19).

Fig 7.19 Mobile phone screenshot of Bluetooth message

On clicking on the link they access a browser interface as shown in Fig 7.20:

Fig 7.20 Screenshot of prototype Storypost interface (shown running on an iPhone)

In the interface a choice of stories is listed. By clicking on a story they access an mp3 file (sound file), which is approximately 1 ½ minutes to 2 minutes in length. This is then listened to on the mobile device.

7.9 *Usability Testing*

The first stage of testing was to assess the usability of the prototype.

7.9.1 Method

Participants were asked to take part in a survey. There were six participants, four male and two female. They were not paid to participate. Participants were chosen if they were German speakers. The usability testing took place in the real environment. They were not told details of the project but were told to walk to one particular area in the city and expect a Bluetooth message which they were asked to accept. It was explained that they should proceed with the options that were offered to them until they felt they had used the system enough and then to return to the interviewer to answer some questions about what they had experienced. They were then observed from a distance as they interacted with the application, and then the evaluation process began in an adjacent café. The following questions were used to evaluate the system's usability:

Interface	*Did you understand what you were supposed to do?*
	Did the interaction with the interface work in the way you expected?
	Was the progress through the series of stages of the interface clear?
Technical	*Did everything work?*
	Do you think you would normally accept a Bluetooth message from an unfamiliar device?
	Was the sound quality acceptable?
	Was the download time for the story too long, too short or just right?
Timescale	*How long did you interact with the application?*
	How many stories did you listen to, and why?
	Did you find the length of the stories to be too long, too short or just right?
Content	*Did you find the content interesting?*
	How did you decide which stories to listen to?
	Did it make you think about the place differently?

7.9.2 Results

Observation

In terms of the user attention this was initially directed to the device as they interacted with the first stages of the interface. However once a story had been selected the individual could be observed seeking out the place being described in the story and either literally moving to the place or more simply just looking at it whilst listening to their story. This was a benefit of the interface being sound-based for the story delivery. Users either kept the device at hand level, as though they were reading a message, or held it to their ear once the sound began to play.

Interview

Users generally reported that the interface worked, and that they found navigating through the various stages easy to understand. Since users were not expecting to receive content in the form of a sound file it was reported that this was initially a surprise, as they had expected a picture. In terms of the technical aspect of the application the system worked. However one user reported that they did not feel they would normally accept a Bluetooth message from an unknown device. This was perceived as a privacy issue, and a concern about receiving advertisements. A further criticism was the length of the story, which some users felt was too long. This meant they only listened to one or two stories. One user stated that the shorter the stories were the more they would access them. Users reported liking the fact that they had a choice of stories, and they used the title of the story to assess what they thought the content would be about. However some users found that the actual content of the story did not match their expectation of what it would be about from the title they had chosen. Typically users reported that they found the stories interesting and also amusing, and that the content was new to them. This was the case for one user who was actually reasonably familiar with Weimar.

7.9.3 Discussion

Key Usability and Design Issues and Discussion of Iterations in the Working Model

Language: A key design issue is that of language. In the design scenario, the typical user is someone who is familiar or semi-familiar with Weimar. This would mean that they could have a range of native languages, but the distribution would be a mixture of German and English speakers. In the prototype system the distribution of stories is approx. 70% German language, 30% English language. Theoretically it would be possible in the next iteration to translate German stories into English and vice versa. However the system design relies on the fact that the person whose story it is, narrates the story in his or her own voice. This means translation is not appropriate. The second aspect is that typically German speakers will only choose German language stories and vice versa. Bearing in mind that the vast majority of people who visit Weimar are German speakers (87% according to Weimar Tourist Office Statistics for 2006), it seems appropriate to implement the system initially in German only. Once the user aspect of the system is implemented where users can also record their own stories and upload them to the system, this would create more possibilities for stories in a range of languages.

Content Delivery and Bluetooth

There are perceived privacy issues with Bluetooth technology. The system relies on users accepting a Bluetooth message to initiate the interaction. The prototype works on a scenario where people in the city receive ad-hoc messages as they move around the city. This setup does not allow for differentiation between people who may want to engage with the Storypost system and those who may choose not to. A solution to this is an opt-in setup, where the user agrees at a particular point in their stay or visit on Weimar to 'activate' the system with their Bluetooth device. This would mean they enact some form of agreement to participate in the Storypost system, and also that they have the ability to deactivate their participation as they require. This setup would be activated through the user's Bluetooth chosen name on their mobile device which would give them a unique ID and identifier. The system would need a level of technical authentication with specific Bluetooth names, not just at individual nodes, but also as a system.

Story Length

Users reported that the stories were too long and that there was also too much choice. The stories should be edited to be a maximum of 1 minute 30 seconds in length, which also reduces download time. Secondly in the working model the list of stories per location should be limited to three options at any one time. These three options should be randomly selected from a larger database of stories, so that a person visiting the same location twice would be offered a different selection of stories on their second visit.

7.10 Working model

A prototype working model of the Storypost application, with the iterations described above, is available for testing in the environment.

7.11 Future Work

The system proposed has been developed to working prototype stage, and has been usability tested. The next key step is to implement a working model in the urban space and to undertake quantitative testing of the effect of the system on spatial knowledge acquisition. Although the system has significantly different characteristics and interaction models to a mobile map, it would be possible to make some indirect comparisons between the effect on learning in urban space of the two spatial information formats. It is intended this would be completed by running an empirical study which would test for both learning of abstract quantitative spatial relationships (such as those covered in the study discussed in Chapter 4), but also memory for qualitative spatial characteristics specific to the test environment.

A further aspect of the development of the project is to seek ways to embed it into the cultural and social programme of the city of Weimar, as well as the technical infrastructure. This involves negotiation with the city authorities to establish ways in which the working system can be of benefit to the city, and practical aspects of how it may be installed within the urban fabric.

7.12 Conclusion

The system proposed offers a creative response to the problems identified through the empirical work described in the preceding chapters. The proposed system comprises a series of modular elements making up a system intended to support spatial learning in a specific environmental setting. The requirements of the system are identified through a series of site-specific empirical studies of how wayfinding is enacted in the setting of a defined area in Weimar. These identified how wayfinding situations are situated in the urban space, and how information might best be meaningfully interwoven into the experience of the space. One element of the system is developed to prototype working model stage and the results of usability testing on the prototype are discussed. The design solution proposed does not seek to provide a complete solution to the research problems identified, but puts forward an outline of an alternative to an abstract map-based interaction with spatial information. The Storypost implementation described suggests an approach to supporting wayfinding in the city based on a situational experience of space and through the enaction of localised technologies.

8

Conclusion

8.1 Abstract

This chapter takes the conclusions of Chapters 4 through to Chapter 7 and combines their individual outcomes to provide an assessment of their contribution to the original research questions. It then proceeds discussing the implications of the research outcomes in a wider academic and application-based context. It concludes with a statement of future research directions that could arise from the work forming this thesis.

8.2 Summary

Over the last fifteen years media and urban theorists have attempted to document the changing nature of urban space as mediated by new technologies, variously naming these new urban forms; the '*space of flows'* (Castells 2004), *'city of bits'* (Mitchell 1995), and '*trans-physical city'* (Novak, 1992 p. 266). These studies mainly concentrated on the impact of media such as the Internet and virtual reality on urban space. From a computer science perspective the paradigm is also changing; to date theorists have approached the growing field of ubiquitous computing from the standpoint that technologies should essentially disappear into the background (Weiser 1994).

The issue that both fields seem to encounter is a perceived conflict where '*we are torn between these parallel but disjoint spaces*' (Ishii & Ullmer 1997, p. 234) i.e. the 'real' space of the city and those of mediated environments. Mobile and wireless technologies no longer offer a substitute for experience or provide alternative models for urban space, they are instead converged and integrated; one might say that the technology has leaked out into the city. This layering of spaces is not unproblematic, and raises fundamental questions about how individuals relate and act in their spatial world when they also experience it through technology. The idealised notion of 'anytime, anyplace, anywhere' oversimplifies the issues which arise from being physically and socially on the move. Instead it was proposed that our movement through urban space requires an understanding of a relational interweaving of knowledge, both that sensed in the immediate setting and that arising out of a background of experience. Thus interaction can be seen as occurring in a field of affordances, where various dynamic aspects of space move fluidly into focus to inform particular actions, whilst others slip into the background.

This work sought to address our interaction with technologies in a spatial world through grounded empirical research. It was based in the problem domain of wayfinding; literally the process through which we find our way and orient ourselves in our everyday lives. The research was based in the premise that our spatial environment provides orientation and structure to our movements and actions, and that the way we interact with it affects the manner in which we acquire spatial knowledge. In particular its approach was to investigate the acquisition of spatial knowledge and our action in spatial settings, and understand how perception and learning is changed through our interaction with mobile and wireless technologies. In this sense the use of wayfinding as a focus for the work is not secondary, but a metaphor for providing a way for us to understand how we navigate both the physical world comprised of spatial information and the world of digital information.

In order to do this the concept of wayfinding situations was introduced; where wayfinding was seen as a changeful and rich process affected by both background knowledge and the contingencies of the situation in which the wayfinder acts. This included an understanding of the situation as including the individual, the environment and the technology which guides the situation. These aspects of the situation were not seen as acting independently, but as fundamentally inter-related such that it is not based on interactions, but instead was understood as enacted. Thus the wayfinding situation is constructed dependent on a whole range of changeable circumstances, most of which are local in relation and effect.

Arising from this approach a series of empirical studies was described which sought to investigate the characteristics of wayfinding situations; firstly by focussing on how mobile spatial technologies affect spatial knowledge acquisition in the environment, and secondly by studying the effect on perception and behaviour in urban space when it is embedded with wireless technologies. This empirical work was structured around methodologies from Psychology, Architecture, Sociology and HCI, such that the approach was interdisciplinary. It was explained that the topic of wayfinding situations such an approach was required in order to effectively investigate the interrelated mental, spatial and social aspects that affect the enaction of such situations. The final stage of the research implemented these findings into a proposal for an application to support wayfinding situations based in a particular urban setting. This application sought to describe not an absolute solution, but a site-specific example of how to respond to the problem of supporting spatial learning when the space is enacted through mobile and wireless technologies.

8.3 Review of Research Questions

The research questions of this thesis were (these were introduced in Chapter 3):

Research Question One:
Investigation: What is the nature of individuals' spatial knowledge acquisition when space is experienced through mobile and wireless technologies?
Research Question Two:
Evaluation: How is this experience of urban space changed and how can we enable technologies to respond to the situational aspect of the interaction?
Research Question Three:
Implementation: How can we find better ways of enabling the situated interaction between individual, device and urban space so that wayfinding in the environment is supported?

Research Question One was answered by the methods devised in Empirical Study One and the discussion of the results and outcomes of that study. The empirical work provided an understanding of the effect on spatial knowledge acquisition in an urban environment when it is supported by mobile spatial information.

Research Question Two was answered by the methods devised in Empirical Study Two and the analytical outcome of that study. This research provided an understanding of the effect on perception and behaviour in respect to the situated nature of interactions and their relationship to the physical urban environment in which they occur.

Research Question Three is answered by the application described in Chapter 7. A prototype was designed based on the understanding of physical and social context provided by Studies One and Two. The two empirical studies were used to characterize wayfinding situations and the prototype, called Storypost, was designed as a response for exploring alternative approaches to applying these findings.

The main outcomes from this research show that using a holistic approach to understanding physical and social context of an urban environment results in a more meaningful understanding of the characteristics of wayfinding situations. Results also show that this is a useful and understandable mechanism for incorporating elements of the user's current situation thus forming a link between the digital, physical and social layers of mediated urban environments.

8.4 Scientific Contribution

8.4.1 Contribution One

* Understanding of the effect on spatial knowledge acquisition of using mobile maps to navigate an urban environment

Wayfinding has stimulated a large body of high quality theoretical and empirical work looking at the many aspects of the activity. In particular the work of Passini and Lynch established a more generalised approach to the subject, which is still a reference for many in the field. From the perspective of spatial cognition, notably Golledge (Golledge 1999), Montello (Montello 1998), Freksa (Freksa 1999), and Tversky (Tversky 2001) among others have established widely accepted perspectives on how individuals undertake spatial tasks guided by internal representations. Arising from this work researchers have sought to understand the role of technologically assisted environments. In the nineties much empirical work was undertaken which studied the role and effect of navigation in virtual environments (e.g. Conroy 2002, Darken & Peterson 2002). The Noughties have seen the focus shift onto the role of mobile technologies, although this work is still fairly under-developed. In particular the work in the field has tended to focus on lab-based empirical work, and consequently the important effect of real-world urban conditions is often overlooked. Therefore the work described in empirical study one makes a significant contribution in that it provides a solid methodology for investigating spatial knowledge acquisition in urban environments and how this is affected by an individual's interaction with mobile spatial information. In addition the important role of such wayfinding assistance in the acquisition of spatial knowledge extends existing work in the area by Thorndyke and Hayes-Roth (Thorndyke & Hayes-Roth 1987).

8.4.2 Contribution Two

- Understanding of how spatial perception and action in urban public space is affected by the presence of wifi technologies

A great deal has been written about the impact of communication technologies on perception or image-ability of urban space, most notably that of geographers such as Graham and Marvin's book 'Telecommunications and the City' (Graham & Marvin 1996) and also Michael Batty in a number of published papers (Batty & Miller 2000, Batty 2002). In correspondence with Stephen Graham he confirmed this and stated that '*I agree that image-ability is really important. I suppose there are two issues: image-ability of navigable electronic domains and image-ability of the hidden technical ICT infrastructures of cities*' (personal correspondence 2 October 2006). Batty and others have also extended this position to question the way in which space is traditionally perceived. This has lead to many to call for a re-evaluation of traditional conceptions of urban space (Batty 2002, Dodge

& Kitchin 2007, Moss & Townsend 1999). In particular the focus has been on the lack of a visible presence of such networks, and the consequent effect on spatial perception. Although this range of work has been widely accepted as valid it has tended not to be based on empirical studies with participants. The second empirical study described in this research has sought to establish this speculation based on a study in a real urban setting. The study found that people do not imagine the presence of such technologies in visible terms, but instead in terms of possibilities for acting and connecting to social networks.

8.4.3 Contribution Three:

* Alternative method for supporting individuals as they enact wayfinding in urban public space with mobile and wireless technologies.

In the field of HCI there has been a large body of work based around the concept of context-aware computing and social navigation. This has involved much evaluation (e.g. Cheverst 2000, Oulasvirta et al. 2003) and proposals for how technological applications can respond to real-world changing conditions as a person moves in space. Yet this work has tended to focus on technological solutions where the effect on individuals is explored at the stage of usability studies. Although the facet of the spatial setting has been highlighted as important, most of the studies have not really come to understand how the characteristics of the spatial setting can be used to inform the design of such systems. The work described in Chapter 7 has sought to propose a technological application which derives its design directly from a specific urban setting.

8.5 Future Research

This thesis has created a clear agenda for future research together with an indication of a methodology for undertaking this work. In essence this thesis has identified problems through empirical study. The next stage of the work would be to investigate the phenomena identified.
Arising from the first empirical study the issue of the differences in spatial knowledge for those who learned the space with mobile maps was substantiated. Arising from this proposals were made about the nature of the schematic knowledge and the way the space was conceptualised. In order to be more specific about the nature of spatial knowledge acquisition with mobile technologies a second stage of empirical work would be required to test the hypothesis developed.

The second study in a sense established only a negative; that knowledge about a space embedded with wireless technologies is not necessarily conceptualised in a visuo-spatial manner. It was found by derivation that the space was instead seen in terms of possibilities for certain types of behaviour, but since the empirical work was not based in methods from Sociology these results did not reveal fundamental insights into exactly what sorts of behaviour this was, or how it fitted into a wider context of people's everyday social activities in a spatial setting. Since the study focused on the use of public space, it was affected by the fact that empirical work is problematic to undertake in this setting since it is not possible to work within controlled conditions. In addition it would be necessary to focus on a specific participant group to enable direct comparison across a section of users. Such a study would also need to take place over a longer period of time, possibly up to a year, to enable a much broader and comprehensive data set to be obtained and studied. In such a study participants would agree to be part of the study for a specific period of time and record their behaviour on a daily basis. This record would include a description of when they accessed any form of mobile or wireless technology, how long and most importantly the location. Also critical would be to know what activity they undertook through the technology; checking email, looking up a place to eat, making a phone call to a friend etc. Once such a data set had been obtained it would also be able to build up a pattern of social connections, how people operated within social networks and how this might relate to the place in which they chose to enact social behaviour. Ideally this would start to build up an understanding of how the place in which a person is acting is linked to the type and manner of interaction, something. This would start to establish how people 'find their way' not necessarily in a purely spatial sense, but how they navigate social networks embedded in spatial settings.

However the most immediate work required as the obvious next step of this research is to test the working model of the Storypost application for its effect of spatial knowledge acquisition in the urban setting. The features of the system were developed out of a response to the findings of the empirical work, but this was not a direct implementation of the findings. Instead it was a creative solution to a perceived set of problems. In order to establish whether the solution does indeed have validity it is vital to assess whether people who accessed the Storypost system in Weimar ended up with a better 'memory' for the place. There are two possible methodologies for proceeding in obtaining results and this would in a sense depend on the field or discipline in which it is required to substantiate the work. The first option would be to proceed with psychological methods similar to those from empirical study one. A version of the system would be developed specific to the empirical setting in study one; the allotment garden environment in Bremen. Working through the same process of development of requirements the nodes and structure of the setting would be derived from interviews with the residents of the allotment setting. Following this the residents of the setting would be asked to record their stories about the place. Thus the 'map' of the setting would be developed, not from cartographic representations of physical features and configurations, but instead from verbal recordings of local memories about the place. In the same manner as that proposed in the Storypost application, these stories would be linked to the key nodes in the setting and embedded with Bluetooth technology at these nodes. Once such an alternative 'map' of the setting had been developed then it would be possible to recreate a learning phase essentially similar to that described in empirical study one, but with the participants learning the space through the Storypost application. This would be compared against the two control groups; this time the mobile map and map formats. The test phase could then be run to assess the nature of spatial knowledge acquisition for the space depending on the form of spatial assistance accessed. Although such an empirical study would hopefully enable quantitative analysis of acquired knowledge in a manner that would have some methodological validity in a field such as Cognitive Psychology, it has definite limitations in terms of actual usefulness of the results. The outcomes of the study would study differences in essentially metric spatial knowledge, and consequently the type of knowledge tested for would not reveal the full facets of the 'situation' in the sense that wayfinding situations have been discussed in this research. In fact one of the key findings of the research is that spatial assistance delivered through mobile and wireless technologies results in non-metric spatial knowledge.

Therefore a second option would be to develop a methodology set within the framework of the type of knowledge about a wayfinding situation that has been discussed in Chapters 5 and 6 of this thesis. To do this an ethnographic approach would be necessary to establish to try and contextualise the social as well as the spatial qualities of the knowledge acquired. This would follow the format of the requirements studies undertaken in Chapter 7, but would be more detailed and rigorous in nature. A further aspect of the work would not be to simply observe or study behaviour, but to deliberately attempt to disrupt hypothesised behaviour patterns to study how people adapt and respond. It is proposed that this method could capture the affordances of a wayfinding situation far more meaningfully than trying to make inferences from observation. Thus a control situation or scenario would be established and a series of different manipulations of the situation set up to see how participants adapt to the different characteristics. This would be followed by interviews to establish the individual's account of the wayfinding process and how they responded. For example a situation would be given where a participant would be asked to find a person (someone not directly known to them) in an urban setting. This method has been used by the author in a trial session, which was entitled 'Find Eric', and involved a series of participants in groups of four people, being asked to find a local person in the setting (in this case the setting was a defined 1km square area of San Jose Downtown, USA). The participants were not familiar with the environment, and were only given a photo of the person in order to guide them. In this test experiment participants had to find ways of gaining local knowledge in order to locate the person in the space. This involved asking people and then following guidance about where to go. In this test run participants movements and observations were not recorded, but as a method it showed a lot of promise in terms of establishing the social as well as the spatial features and structures that people use to guide their actions in a wayfinding situation.

Therefore in the proposed study the participant would then have to act on both their social networks, as well as their knowledge about the physical configurations of a spatial setting in order to complete the task. The task itself would then be interrupted in three different ways; firstly a person familiar with the environmental setting would undertake the task alone, but would be given some background information in order to help them. This information would be presented digitally. The second scenario would be that the wayfinder (again familiar with the environmental setting) would be asked to team up with one or more persons in order to complete the task. The third scenario is that the person completing the task would have no knowledge of the setting, and would be told to use any method they felt appropriate in order to complete the task. Participants' movements and reactions would be recorded through video, and participants would be asked to 'think out loud' in order to record decisions during the task. Once the participants had completed the task they would be shown a video of their behaviour and asked to explain and reflect on their behaviour during the situation. This data would then be analysed to define the common characteristics of a situation and to assess what structures people use to guide their actions.

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How Satnav Took our School Trip Up a Back Alley. The Evening Standard, 22nd March 2007, http://www.dailymail.co.uk/pages/live/articles/news/news.html?in_article_id=443993&in_page_id=1770 (retrieved 22nd March 2007)

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Appendix A

Selected Papers Published During Candidature

Book Chapters

Willis, K., Hoelscher, C., Wilbertz, G. (2008 accepted for publication). Understanding Mobile Spatial Interaction in Urban Environments. In Minker, W., Weber, M., Kameas, A., Hagras, H., Callaghan, V. (Eds). Augmented Intelligent Environments, Springer

Willis, K, (2008). Information Places: Interfaces Between Physical and Digital Space in Foth, M (Ed). Urban Informatics. ICS Global.

Willis, K (2008). Spaces, Settings and Connections in Aurigi, A., De Cindio, F. (Eds) Augmented Urban Spaces: Articulating the Physical and Electronic City. UK: Ashgate Press.

Willis, K. (2007). Situated Interactions: Spatial Setting and Mobile and Wireless technologies. Encyclopaedia of Mobile and Wireless Communications. Taylor and Page, US

Willis, K. (2007) Sensing Place: Mobile and Wireless Technologies and Urban Space in Frers, L., Meier, L (Eds) (2007). Encountering Urban Places - Visual and Material Performances in the City, Ashgate Publishing

Edited Volumes

Willis, K., Chorianopoulos, K., Struppek, M., Roussos, G (2009 to appear). Shared Encounters. Springer, UK

Eckhardt, F., Geelhaar, J., Colini, L., Chorianopoulos, K., Willis, K., Hennig, R. (2009 to appear). MEDIACITY, Frank & Timme, Berlin

Journal Articles (with full review)

Willis, K., Hoelscher, C., Wilbertz, G. , Li, C. (2008 accepted for publication). Spatial Knowledge Acquisition with Mobile Spatial Information: Implications for Navigation Applications. Special Issue of Computers, Environment and Urban Systems, Elsevier Press

Full-length Conference Proceedings (with full review)

Willis, K., Holescher, C., Wilbertz, G. (2007). Understanding Mobile Spatial Interaction in Urban Environments. In Proceedings of 3rd IET International Conference on Intelligent Environments (IE07) (pp 61-68).

Li, C. and Willis, K. 2006. Modeling context aware interaction for wayfinding using mobile devices. In Proceedings of the 8th Conference on Human-Computer interaction with Mobile Devices and Services (Helsinki, Finland, September 12 - 15, 2006). MobileHCI '06, vol. 159. ACM Press, New York, NY, 97-100.

Willis, K. (2006-online). Changing Interactions and Infrastructures in Urban Public Space as Afforded by Mobile and Wireless Technologies, IAPS 2006, Egypt

Workshop Papers and Miscellaneous Publications (with limited review)

Willis, K, Hoelscher, C, Li, C (2007). Differences in Spatial Knowledge for maps and mobile maps. Proc. of Cognitively Adequate navigation Systems Workshop, KogWis 07, Saarbrucken

Willis, K., Chorianopoulos, K., Struppek, M., Roussos, G (2007). Shared Encounters. In Proceedings of CHI2007, April 28 – May 3, 2007, San Jose, USA.

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Chorianopoulos, K., Willis, K, Colini, L., Teran, M., (2006). Dousing for Dummies: methods for raising public awareness of invisible communication networks. In Adjunct Proceedings of British HCI conference 2006.

Willis, K. (2005). Situated Cognition in the Use of Mobile Devices for Wayfinding Tasks, Mobile Maps 05 Workshop at MobileHCI05, Salzburg on 19th September 2000

Willis, K. (2005). Mind the Gap: Mobile Applications and Wayfinding, User Experience Design for Pervasive Computing, Pervasive 2005, Munich on 10th May 2005

Willis, K. (2005). Space/Place: urban public space and new media technologies. Urban Spaces and Private Quarters Panel at Conference for Technological and Aesthetical Transformations of Society, TU Darmstadt on 12th-14th October 2005

Willis, K. (2005). Passing Through: Perception of Place and Mobility. Cruising Country Conference, Sydney, Australia, 26-28th May 2005

Willis, K. (2005). The Potential of GPS Technologies to inform an Approach to Understanding Visual Sequences for the Observer in Motion, Generative Art Conference, Milan, Italy, December 2004

Poster Proceedings

Giles, T., Marienek, M., Willis, K., Geelhaar, J. (2007). Hide and Seek. in Poster Proceedings of Fifteenth ACM International Conference on Multimedia, (ACM MM 07), September 2007, Augsburg, Germany.

Li, C., Willis, K. (2006). Dynamic Aspects of Interaction in Wayfinding Tasks. in Poster Proceedings, Spatial Cognition Conference 2006, Bremen, Germany.

Appendix B

Collection of Newspaper Articles on GPS navigation problems

1) NEWS.com.au GPS havoc on French motorway, December 1, 2004 (retrieved 12 January 2005). http://www.news.com.au/common/printpage/0,6093,11553850,00.html

2) The Daily Mail. How satnav took our school trip up a back alley, 22 march 2007, (retrieved 23 march 2007)

3) The Daily Mail. First 'ignore your sat nav' roadsigns go up, 18 February 2007 (retrieved 18 February 2007)

4) The Guardian. Satnav sent driver on the wrong track. March 9, 2007, (retrieved 9 March 20007). http://www.guardian.co.uk/print/0,,329739718-103690,00.html

5) The Register. AWOL satnav system leads to ambulance joyride, 5th December 2006, (retrieved 7 December 2006). http://www.theregister.co.uk/2006/12/05/awol_ambulance_satnav/

6) Yarmouth Mercury. Drivers take wrong turn with sat nav. 1 March 2007, (retrieved 9 March 2007), http://www.greatyarmouthmercury.co.uk/content/yarmouthmercury/

7) The Register. Satnav orders German into toilet. 24 October 2006, (retrieved 7 December 2006), http://www.theregister.co.uk/2006/10/24/satnav_mishap/print.html

8) Miscellaneous German newspaper clippings

news.com.au

GPS havoc on French motorway

Correspondents in Nancy
December 1, 2004

AN ELDERLY motorist driving along a 130km/h expressway in eastern France caused an accident when he followed the advice of his onboard GPS computer - and made a U-turn to drive into the high-speed traffic.

Police said the hapless 78-year-old driver, who was not named, and the occupants of the vehicle he ran into escaped unharmed from the collision late Sunday, but it could have been much worse.

The man told officers his car GPS had told him to "make a U-turn immediately" as he drove along lost on the autoroute near the town of Nancy in search of a hotel.

He did so, not realising the limitations of his satellite navigation device, which guides using verbal directions.

"It's not the first time we've had a GPS incident," one of the officers said, recalling the time a police vehicle found itself face-to-face with a motorist going the wrong way in accordance with his computer's instructions.

The Associated Press

This report appears on NEWS.com.au.

Click here to print

Daily Mail — 24 HOURS A DAY

22/03/07 - News section

How satnav took our school trip up a back alley

The school outing to Hampton Court Palace ought to have been a fairly simple journey.

A glance at a map would have shown the coach driver that most of the trip was motorway, followed by about three miles through South-West London to the gates of King Henry VIII's stately pile.

But the driver chose to rely exclusively on his satellite navigation system - and 60 children spent the whole day being driven round in circles after it directed him to a narrow street in the north of the capital.

The youngsters did not get so much as a glimpse of the palace and a 63-mile journey that should have taken 90 minutes took eight hours.

Scroll down for more...

One child managed to take a picture of the Houses of Parliament as the driver blundered into central London.

Eventually exasperated teachers gave up and the eight and nine-year-old pupils from Orchard Lea Junior School in Fareham, Hampshire, were taken back to the school.

The only break in their journey was a stop for the lavatory.

The incident brought a warning from the AA that drivers had begun following satnav directions 'like robots' and needed to have at least some idea of where they were going before setting out.

"The whole event was a complete disaster" said driving instructor Barrie Cross, whose eight-year-old son Sam was on the trip. "If anything highlights the dangers of using satnav systems without proper understanding, this is it."

The problem began when the coach driver punched Hampton Court into his vehicle's satnav.

It directed him to a road of that name in Islington.

He and a trainee driver following with the rest of the pupils became hopelessly lost as they drove round the capital looking for the Tudor palace.

At one point a teacher got off to buy a map and when this failed to get the drivers back on track, another member of the

At one point a teacher got off to buy a map and when this failed to get the drivers back on track, another member of the group rang the school for directions.

Mr Cross, 39, added: "They rang the school from Islington but in the end they had to abandon the whole trip.

"It would be laughable if it weren't for dozens of children being stuck, and missing out on part of their education.

"They are studying the Tudors and my wife Mandy and I had shown Sam the palace on the Internet and explained why it was important.

"When they came back they were really disappointed.

"All Sam had was a picture he took of Big Ben with a disposable camera put of the coach window."

Zenith Coach Travel apologised and pledged to reimburse the school and take the children on another trip free of charge.

The company, based in Lee-on-Solent, Hampshire, also said its drivers were now banned from using satellite navigation and must instead rely on maps.

The Hampton Court in Islington is 18 miles from the palace, which is in South-West London and therefore easily accessible from Hampshire.

Zenith managing director Alan Jerrim said the drivers' problems were compounded by the fact that the children were riding in two coaches not yet fitted with a tracking device, allowing staff at the company's HQ to pinpoint their location and redirect them.

Mr Jerrim added: "They ended up in all the traffic and roadworks and God knows what else."

The headmaster of Orchard Lea Junior School, Brendon Carroll, said he was hoping a replacement trip would make it up to the children.

Paul Watters of the AA said: "We would advocate still using a map to double check where you are going. Motorists are starting to follow these systems like robots.

"Take a look out of the windscreen - if the road signs appear wrong then it is time to check your route.

"Every driver should have a little bit of knowledge about where they are going before they tap the details into a satnav."

Find this story at
http://www.dailymail.co.uk/pages/live/articles/news/news.html?in_article_id=443993&in_page_id=1770
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The Mail on Sunday — 24 HOURS A DAY

18/02/07 - News section

First 'ignore your sat nav' roadsigns go up

If lorry drivers can tear their eyes away from the satellite navigation system while approaching the village of Exton, they could well save themselves hours of trouble.

There at the side of the road are the first signs in the country specifically warning them to ignore the satnav.

Read more...
- Motorists will MOT cars every two years under new Government plans
- Threat to road-toll rebels who sign petition at work

Owing to a fault in the electronic information system, many drivers are sent through the Hampshire hamlet only to find the lane narrows to 6ft and they get stuck.

Villagers hope that the signs will spare them, and HGV drivers, any further grief, and stop the destruction of hedgerows and verges in Beacon Hill Lane.

Brian Thorpe-Tracey, whose property borders the lane, said he had regularly had to rebuild cobbled kerbs as well as help stuck vans to reverse.

The 49-year-old company director said: 'The problem mushroomed overnight with the advent of satnav.

'About two years ago we noticed a real increase in drivers using the lane. Vehicles are getting stuck and having to reverse back up, damaging the wall and fence. There's even a piece of metal embedded 12ft up in a tree which looks like it's come off a lorry.

'When I've asked drivers why they are using the lane they say they are just following satnav.

'One morning at 1.30am a flatbed truck was coming to pick up a broken-down car and it took out eight metal posts that were holding together a verge.'

Villagers decided they had suffered enough last year and demanded action from the council.

Mr Thorpe-Tracey, who has lived there for 25 years, said that since the signs were put up in November last year there has been a great improvement.

A spokesman for the Department for Transport said: 'As far as we are aware these appear to be the first signs in England telling drivers to ignore satnavs.'

Traffic engineer Neville Crisp, from Winchester City Council, said:

'There were lots of problems with HGVs following their satnavs through that particular area.

'They are following their satnavs but it is totally unsuitable for them to do so.

'Presumably the drivers were using it as a cut-through.

'It was a constant problem - everybody was moaning about it.'

News in brief

Friday March 9, 2007

Guardian

Satnav sent driver on the wrong track

A woman who drove on to a railway line after following directions from her satellite navigation system will not face prosecution, British Transport police said yesterday. The unnamed 52-year-old, from Dorking, Surrey, was waiting at a level crossing at Norman's Bay, near Eastbourne, East Sussex, on January 16 when the device told her to turn left. She drove her Ford Fiesta on to the track, blocking train services between Brighton and Hastings. The BTP said a prosecution would not be in the public interest as the woman had made an honest mistake.

Press Association

Ads by Google

Original URL: http://www.theregister.co.uk/2006/12/05/awol_ambulance_satnav/

AWOL satnav system leads to ambulance joyride

By Tracey Cooper
Published Tuesday 5th December 2006 14:05 GMT

Two ambulance drivers' unswerving obedience to their satnav system ended up turning a 30 minute hospital transfer into an eight hour, 430 mile wild goose chase.

The crew were supposed to be moving a male mental patient from King George hospital in Ilford to Mascalls Park hospital near Brentwood, a 12 mile journey, but a faulty satnav system directed the London Ambulance crew 200 miles off course - and they ended up in Warley, Manchester.

According to paramedic.org.uk, the newish crew, who reportedly had not done this trip before, left King George hospital at 3am and were noticed missing by control at 7am, who queried if everything was okay. The crew then fessed up that they " appeared to be a little bit lost".

A spokesman for the ambulance service told the *Manchester Evening News* that: "We believe that the crew, who had not been to this particular hospital before, followed the directions given by the navigation system, without manually confirming their destination. We understand that they reached the outskirts of Manchester before realising they were heading to the wrong destination.

"The patient was in a comfortable condition at all times while in our care and he arrived safely at Mascalls Park Hospital early that afternoon.

"The problem with the navigation database is also now being fixed."

Which is good news.

A sat nav system wreaked similar havoc back in May (http://www.mirror.co.uk/news/tm_objectid=17083544&method=full&siteid=94762&headline=sham-bulance--nai when an ambulance took almost 90 minutes to take an injured girl to hospital, in what should have been a 10 minute journey.

A recent head-to-head trial between satnavs and conventional maps found that a traditional atlas was the quickest way to navigate, as reported by The Daily Express (http://www.express.co.uk/news_detail.html?sku=805).

The test by consumer group Which? found that two people using an atlas could reach their destination eight per cent faster than those relying on a satnav. ®

Related stories

Satnav orders German into toilet (24 October 2006)
http://www.theregister.co.uk/2006/10/24/satnav_mishap/
London cabbies shun satnav (15 August 2006)
http://www.theregister.co.uk/2006/08/15/cabbies_shun_satnav/
SatNav warriors invade Somerset village (8 March 2006)
http://www.theregister.co.uk/2006/03/08/satnav_menaces_somerset_village/
Satnav fingers bungling burglars (23 August 2005)
http://www.theregister.co.uk/2005/08/23/satnav_bungle/

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Drivers take wrong turn with sat nav

01 March 2007

DRIVERS are being sent on a magical mystery tour through a pretty seaside village, thanks to their satellite navigation systems.

A narrow tree and hedge-lined track in Winterton-on-Sea has become a bustling thoroughfare, with heavy goods vehicles using it as a main route into the village.

Sat nav systems are giving drivers the wrong directions as they come into the village.

Instead of travelling along Hemsby Road into Winterton, drivers are being taken on a mystery tour through a housing estate.

Travelling from Hemsby, drivers are being taken off the main road and sent down a road marked Private Road - The Holway. And they soon find the tarmac turns to mud.

Although the narrow road is clearly signposted "No Through Road", it appears the drivers are putting more faith in their sat nav than on time-worn signs.

They pay no attention and continue along the mud and potholed track.

Parish council chairman David Neve said residents living on The Holway were fed up with lorries using the road.

He told the Mercury: "We have had a problem with the sat nav systems giving drivers wrong directions for about three months and it's getting worse.

"Although The Holway is signposted drivers dismiss this and carry on down the track - which now looks like a tank training ground and is certainly not the main road into a village.

"It is a private road, but no-one knows who owns it.

Residents park their cars along the road and often end up having to move them because the big lorries can't get through."

Since satellite navigation systems became the must-have accessory for drivers,, incidents of this nature have been common across the country.

Earlier this month Hampshire County Council took the unusual step of putting up a sign warning drivers not to follow sat nav systems after lorries kept getting stuck down a narrow lane in the village of Exton, near Winchester. It is thought to be the first sign of its kind in the country.

Norfolk County Council said this week that it had no authority to put up such a sign on a privately-owned road.

A spokesman for the council said: "We appreciate there is a problem but we have no jurisdiction to put a sign up on a private road.

"It is up to residents of the private road to make sure that signage is as clear as possible and the problem is clearly with the sat nav systems," the spokesman added.

Email A Friend

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Original URL: http://www.theregister.co.uk/2006/10/24/satnav_mishap/

Satnav orders German into toilet

By Lester Haines
Published Tuesday 24th October 2006 09:09 GMT

RoTM An "overly obedient" German driver followed his car's satnav system's instructions to "Turn right now!" and duly exited the highway "about 30 metres before the crossing he was meant to take" before piling headlong into a portaloo, the *Sydney Morning Herald* reports.

Mind you, this is not simply a case of a moment's lapse in concentration: before destroying the toilet, the bloke "drove his sport utility vehicle off the road into a building site", then took it "up a stairway" before totalling said convenience.

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The cybernetic capabilities of the WC are not noted, but there is the suspicion that the satnav was acting under instructions to deliver its victim to the nearest man-eating dunny.

Mercifully, the driver's unswerving obedience to his electronic master resulted in the toilet being instantly disabled. His car was also damaged and he copped a fine for his trouble. ®

Fahrerin beschuldigt Navigationssystem

Cottbus (dpa). Eine Cottbuser Autofahrerin hat auf einer Straße mit Wendeverbot kehrtgemacht und dafür ihrem Navigationsgerät die Schuld gegeben. Als zwei Polizeibeamte die Frau zur Rede stellten, gab sie zur Antwort: „Das Wenden hat mir soeben mein Navigationsgerät angesagt." Der Polizeibericht vermerkte darauf am Freitag trocken: „Die Frau wurde belehrt, und dem Navigationsgerät wurde eine Strafe von 20 Euro ausgesprochen."

KENO

Gewinnzahlen: 1, 4, 5, 7, 11, 16, 21, 26, 27, 29, 30, 32, 37, 39, 47, 50, 58, 59, 62, 65

Plus 5: 9 6 1 1 7 (Ohne Gewähr)

Goettinger Tagesblatt 2007

Per Navi in den Graben

Ein Sattelzug mit Auflieger ist auf einem Wirtschaftsweg in Groß Ippener (Landkreis Oldenburg) in einer scharfen Kurve in einen Graben gerutscht. Sein Navigationsgerät habe den Fahrer auf die für sein Fahrzeug ungeeignete, unbefestigte Strecke gelotst, teilte die Polizei am Donnerstag mit. Das eigentliche Ziel des 23-Jährigen sei die Autobahn 1 gewesen. Sachschaden entstand nicht. *lni*

Goettinger Tagesblatt (date unknown)

Navigationsgerät führt in die Irre

25-jährigen Bayern aus dem Wald gelotst

Schleiz. (dpa/tlz) Sein Auto-Navigationsgerät hat einen Münchner bei Schleiz völlig in die Irre geführt. Die Polizei musste den 25-Jährigen wieder auf den richtigen Weg lotsen. Der Mann hatte in der Nacht zum Dienstag auf der Suche nach der Ferienunterkunft in Crispendorf (Saale-Orla-Kreis) den Informationen des Gerätes vertraut und war dabei in ein dichtes Waldstück gelangt, teilte die Polizei mit. Bei einem Wendeversuch fuhr sich sein Auto fest, so dass er über das Handy Hilfe herbei rufen musste. Die Polizei fand ihn nach etwa einstündiger Suche.

5
Ag 3
TLZ
25/7/07

TLZ 25.07.07

Polnischer Busfahrer folgte GPS-Gerät

Paris (dpa). Der Fahrer des am vergangenen Sonntag verunglückten polnischen Pilgerbusses in Frankreich war einem GPS-Navigationssystem blindlings auf die für Busse gesperrte Straße gefolgt. Nach Angaben der Justiz vom Donnerstag entschied sich der 22-Jährige für die Strecke, weil das Gerät diese als schnellere Verbindung anzeigte. Das habe der schwer verletzte Beifahrer den Ermittlern in Grenoble gesagt. Auf der Fahrt versagten vermutlich die Bremsen. Zahlreiche Verbotsschilder warnen auf der Strecke Lastwagen- und Busfahrer vor der Weiterfahrt. Eine Sondergenehmigung für die Bergstrecke gab es nicht. Bei dem Unglück im Val d'Isère starben 26 Menschen.

Goettinger Tagesblatt (date unknown)

Appendix C-1

Empirical Study One: Participants' sketch maps

Page 4 – 15

Map Participants

Schirm

Tanveer

Hasemann

Wesserl

Borkmann

Willbrandt

Demir

Wischka

Keppermann

Schutz

Nehmiz

Neugebauer

Page 16 – 27

Mobile Map Participants

Chen

Salim

Gotthelf

Zedelius

BuelBuel

Schmidt

Tessmann

Heldt

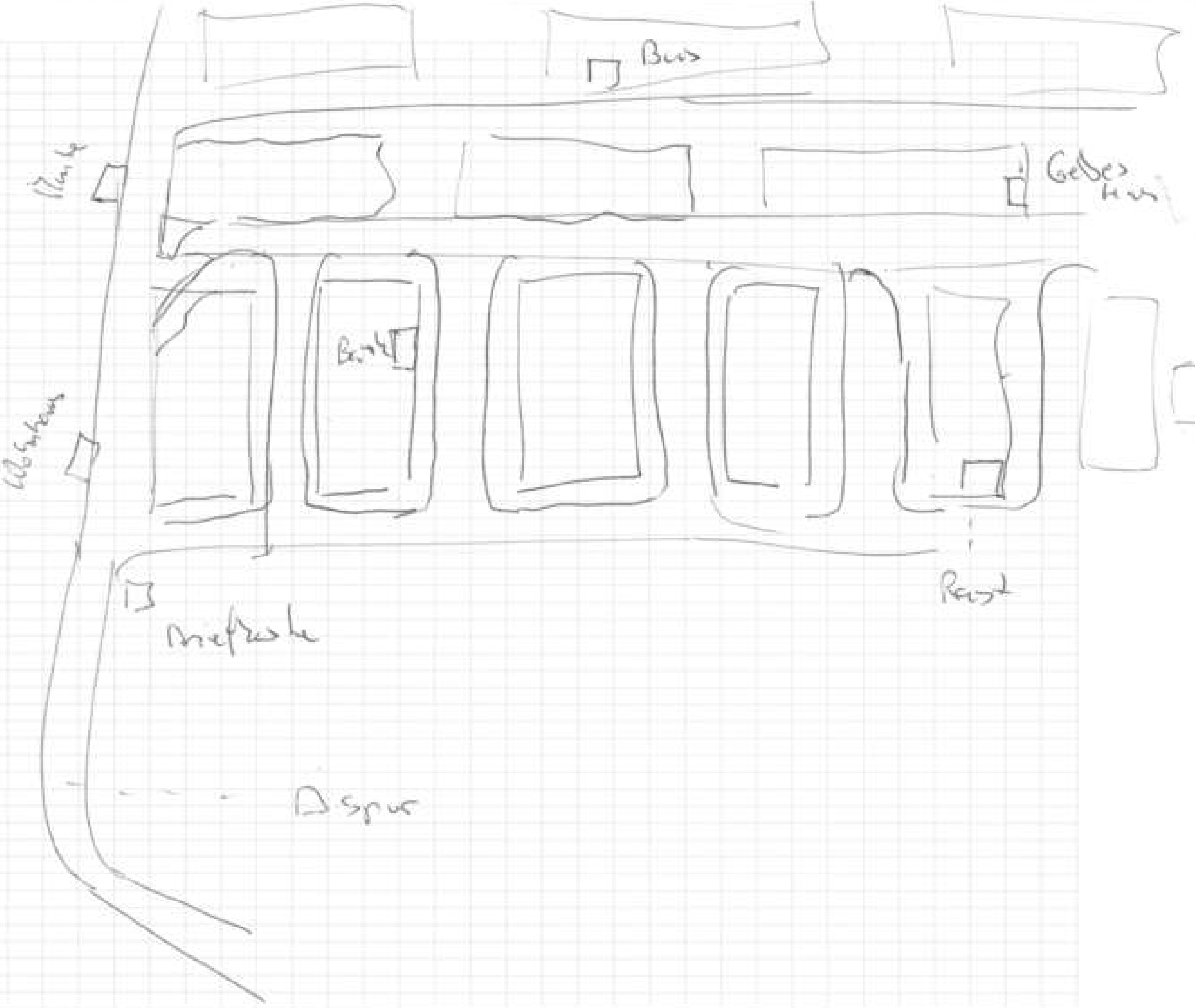
Branig

Markowsky

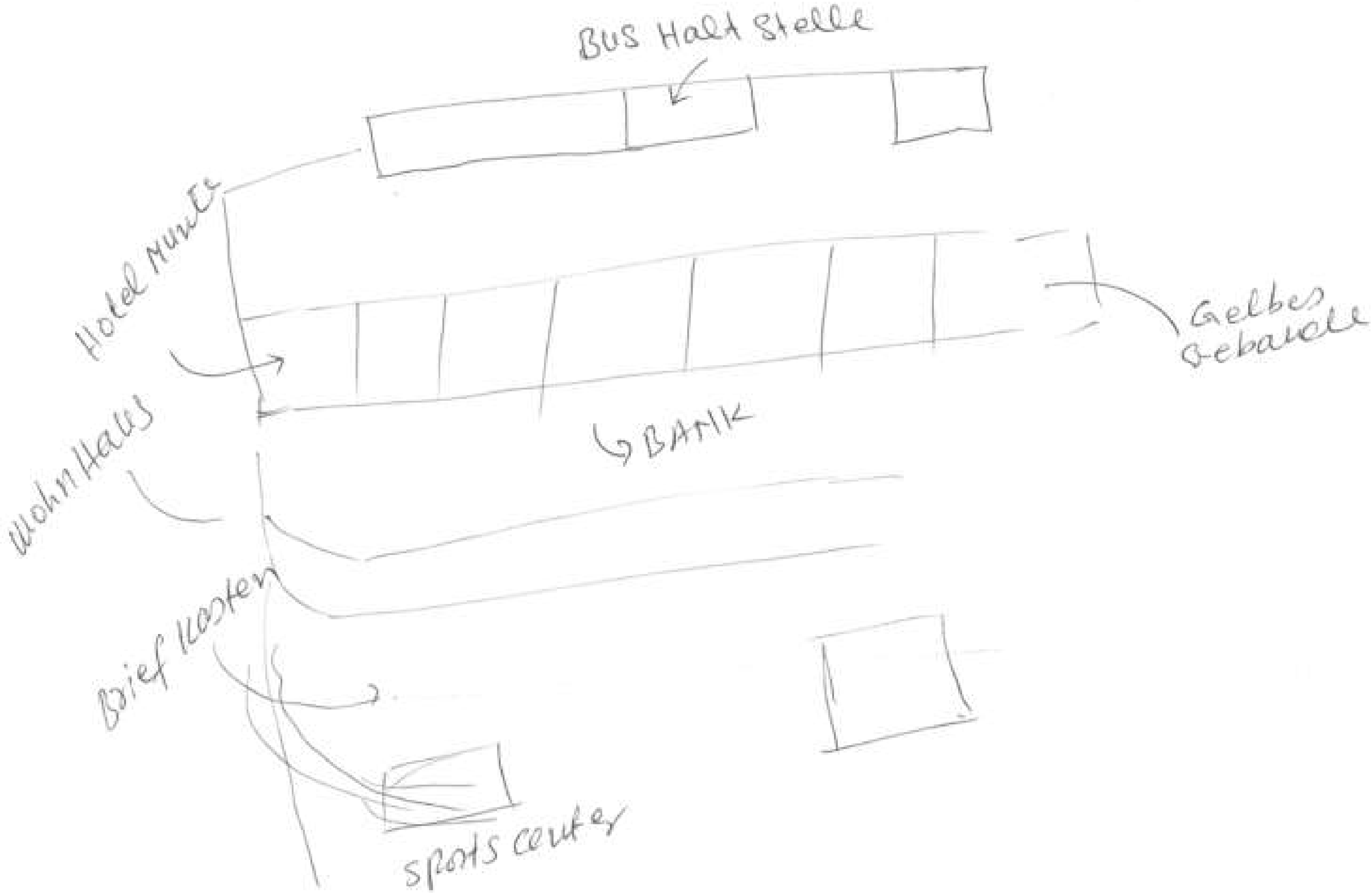
Finken

Khan

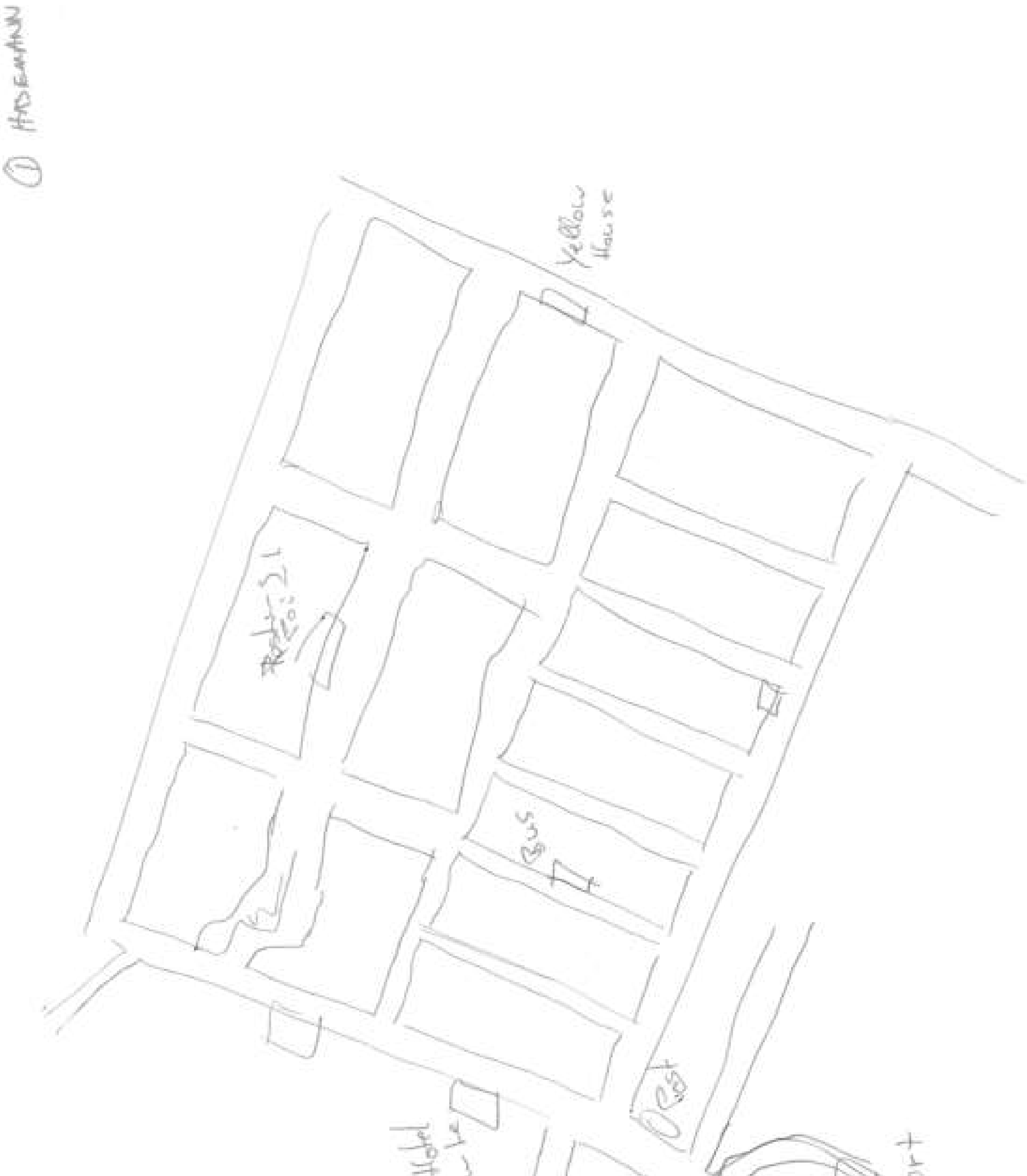
② Schirm



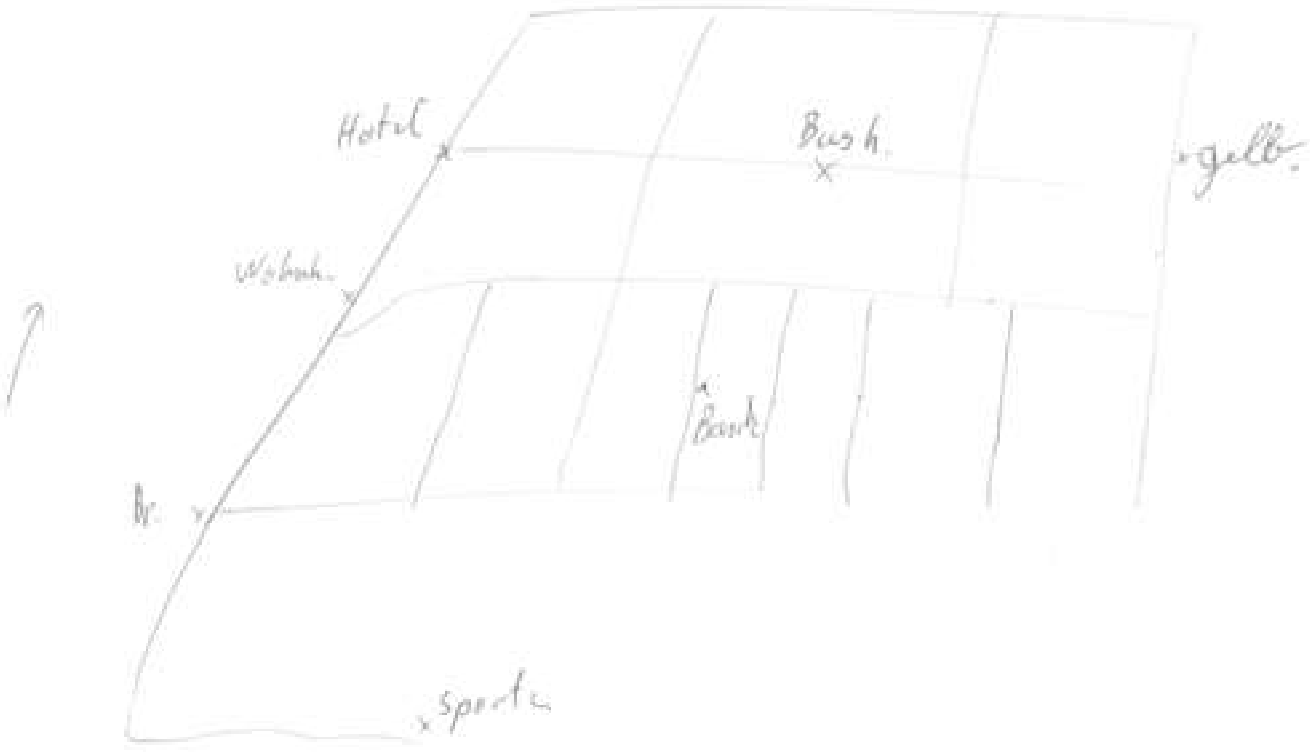
TAWEER (1)



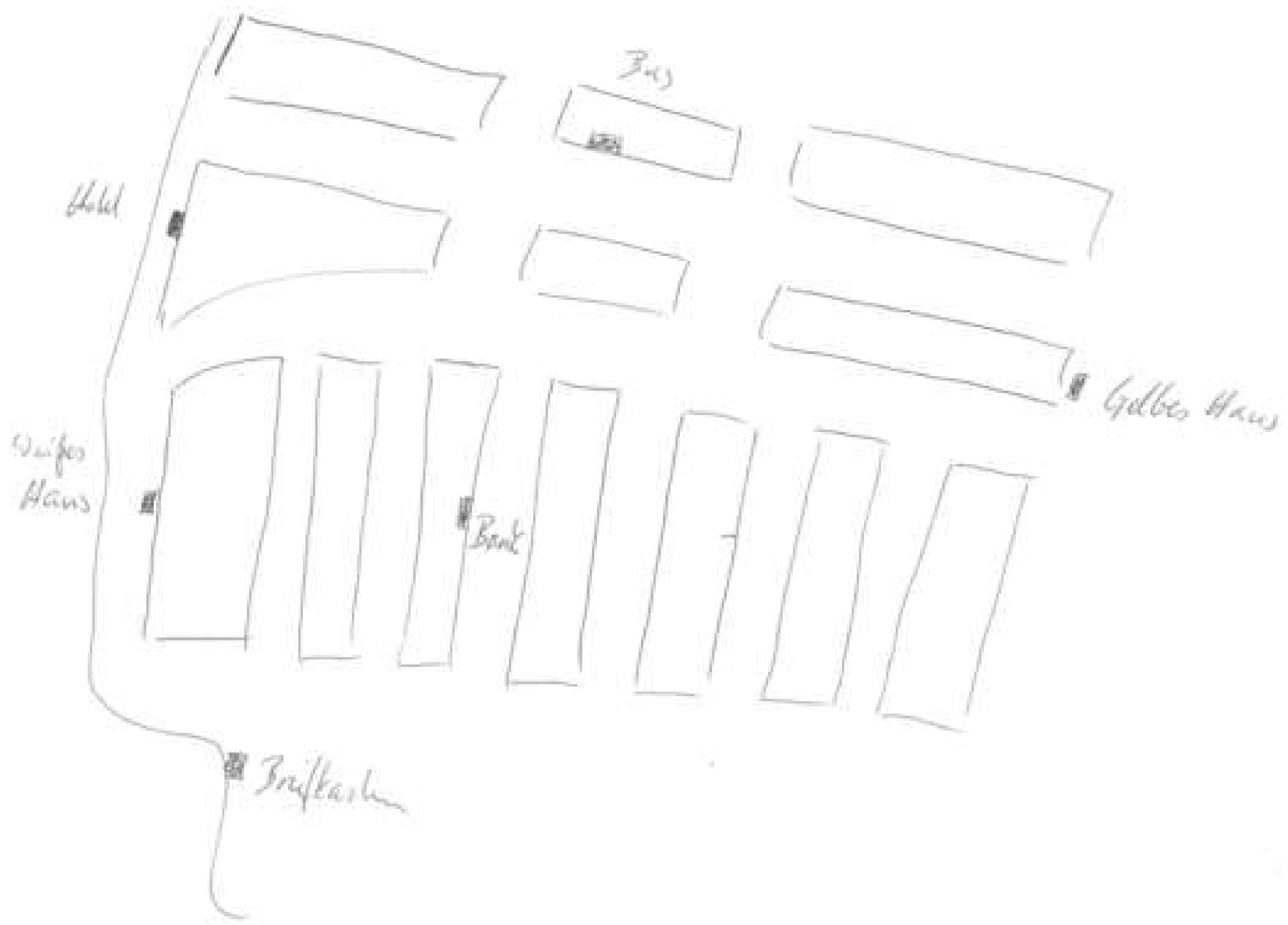
Bus Halt Stelle
Hotel
Gelbes Gebaude
BANK
Wohnhaus
Brief Kasten
sports center

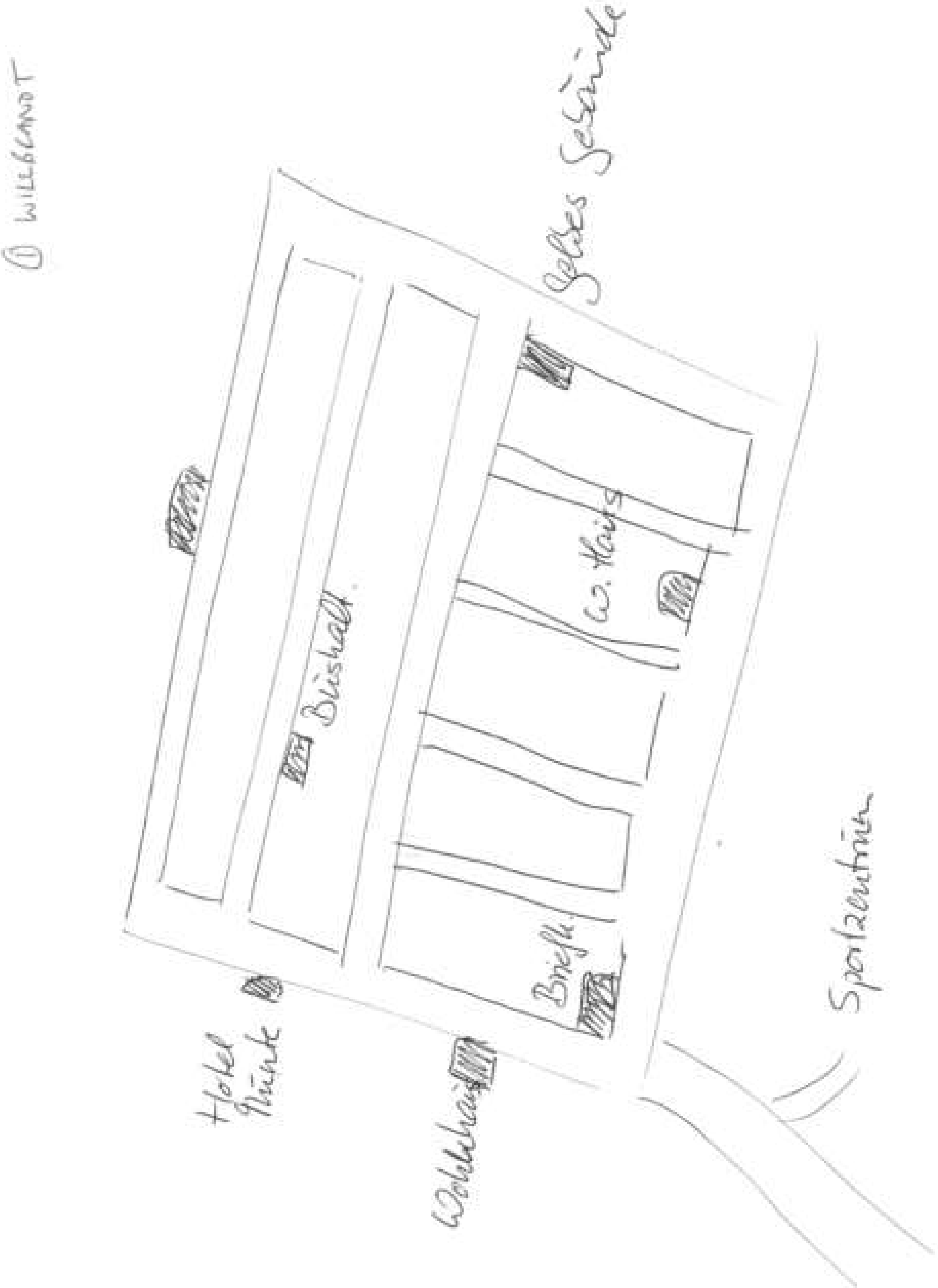

① HASEMANN
Yellow House
Bus
Post
Sport
Hotel

① WESSERL

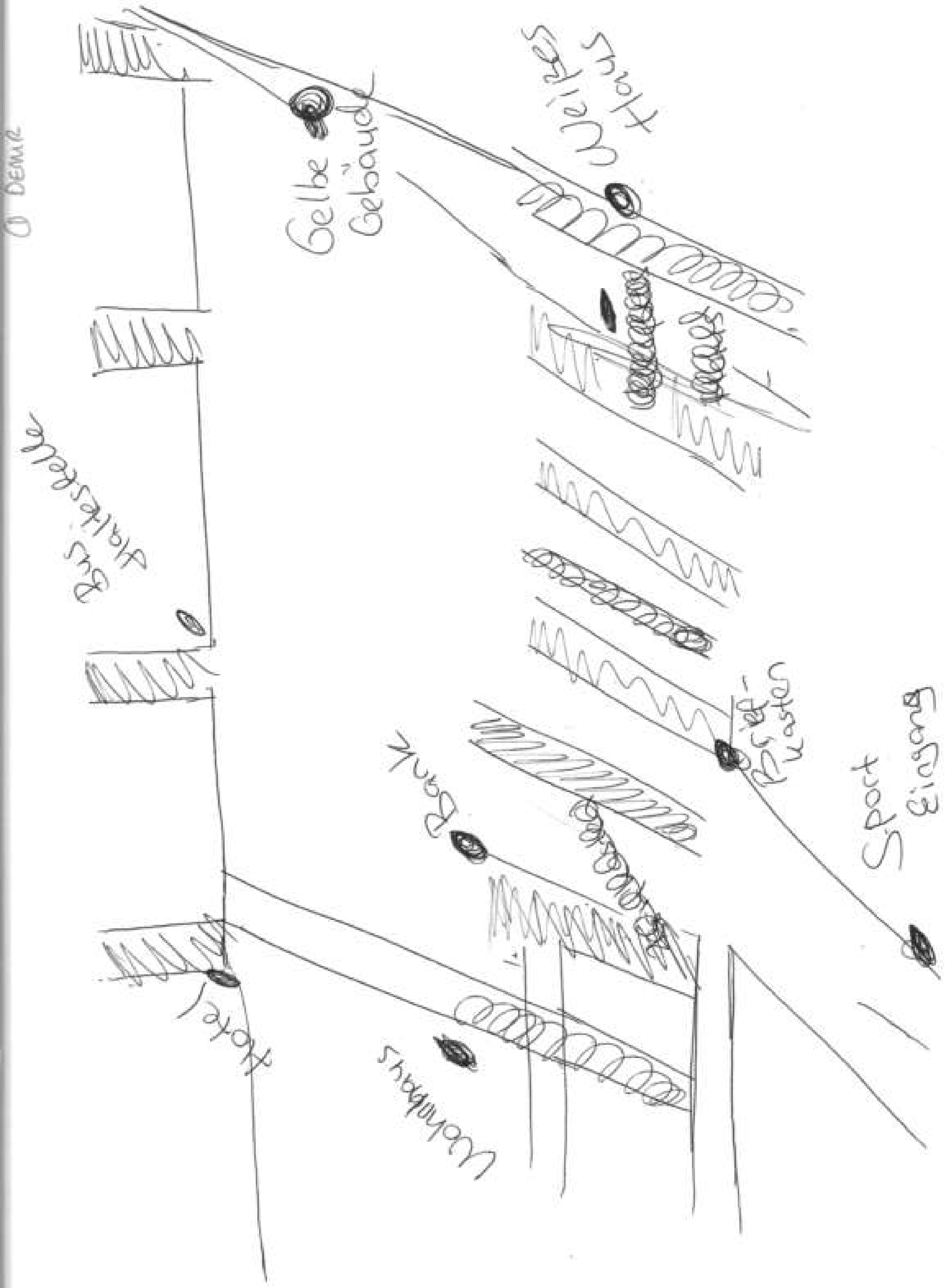


BORGMANN ①



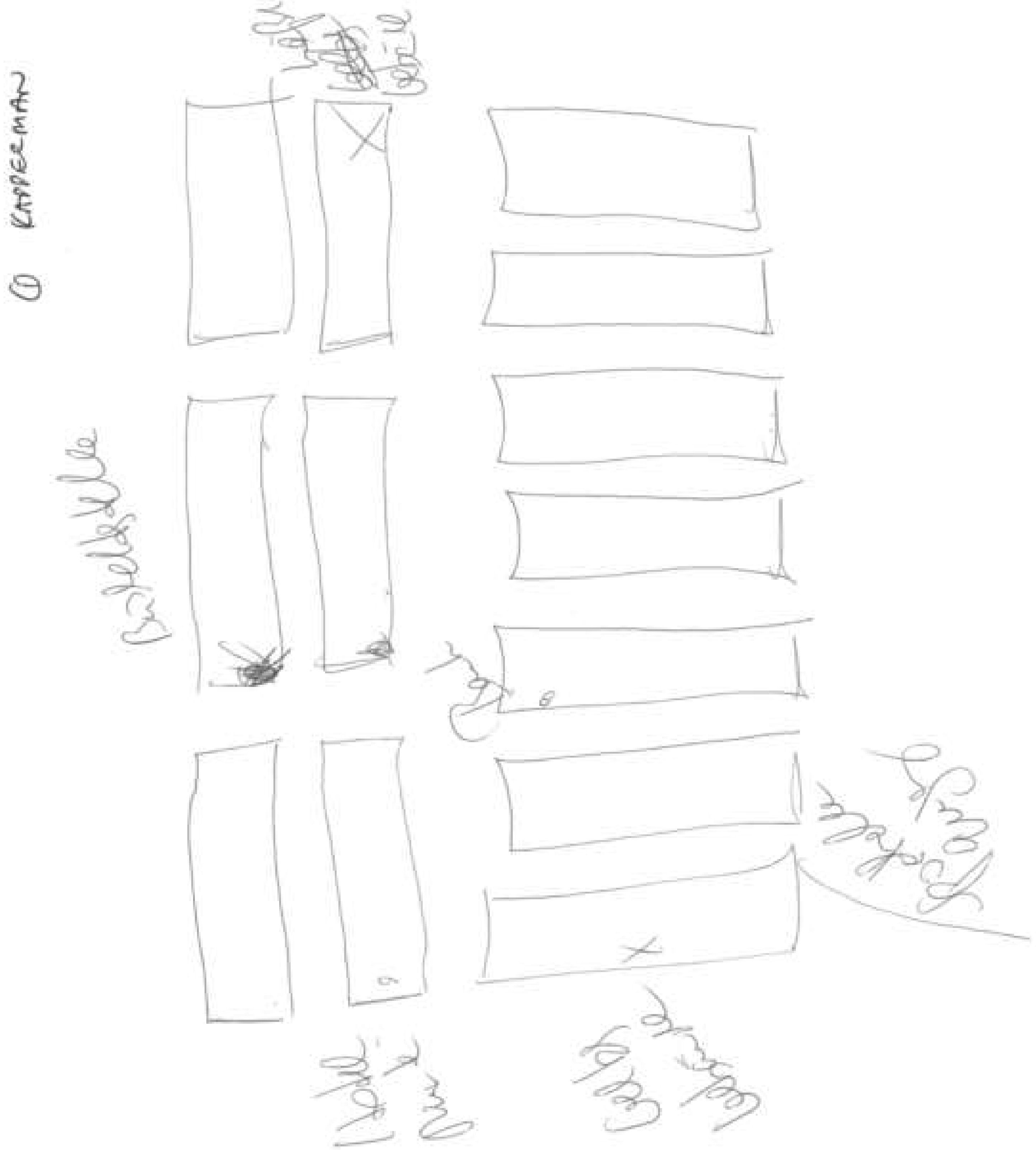


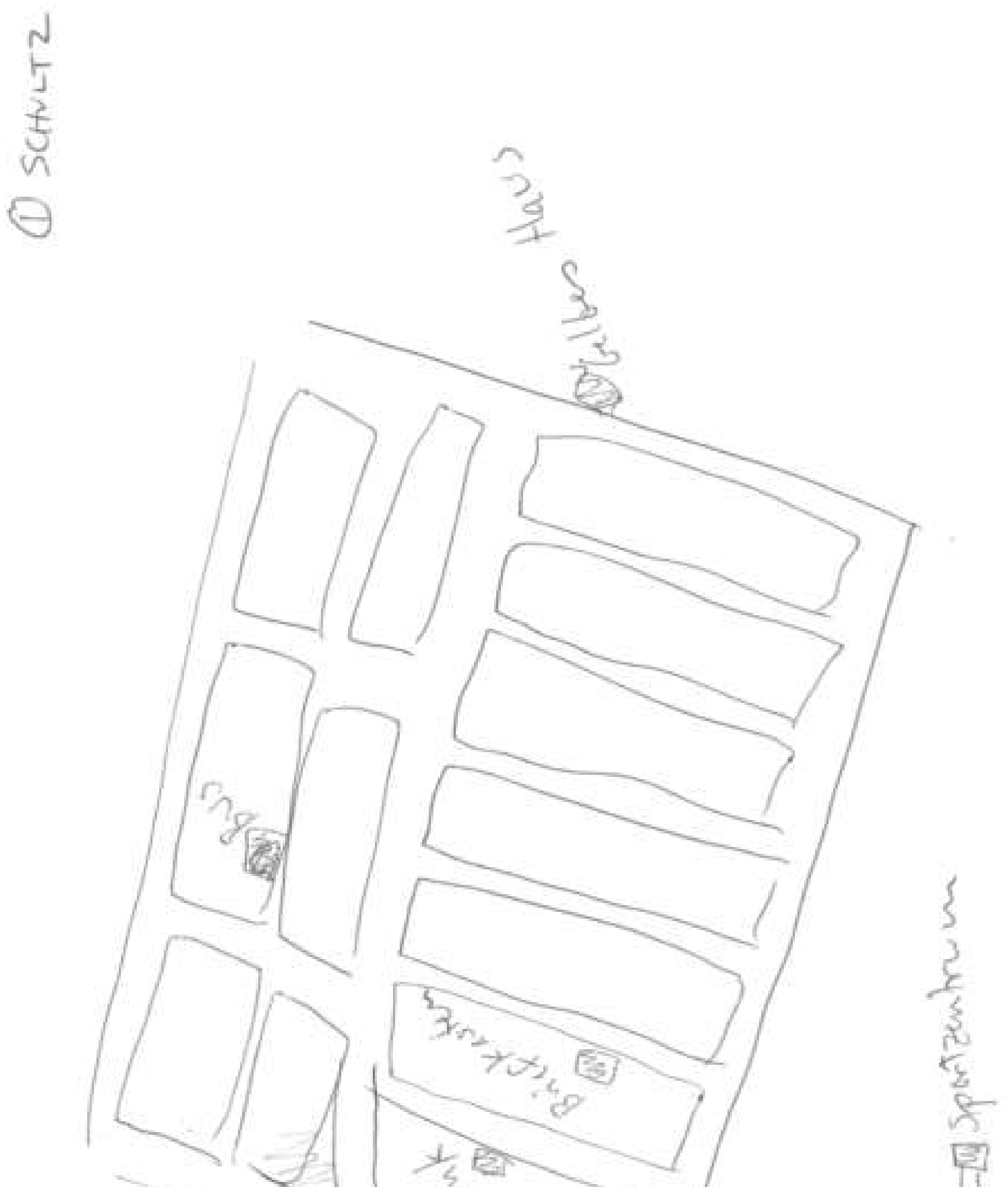
Hotel
Bushalt.
W. Haus
Briefk.
Sportzentrum

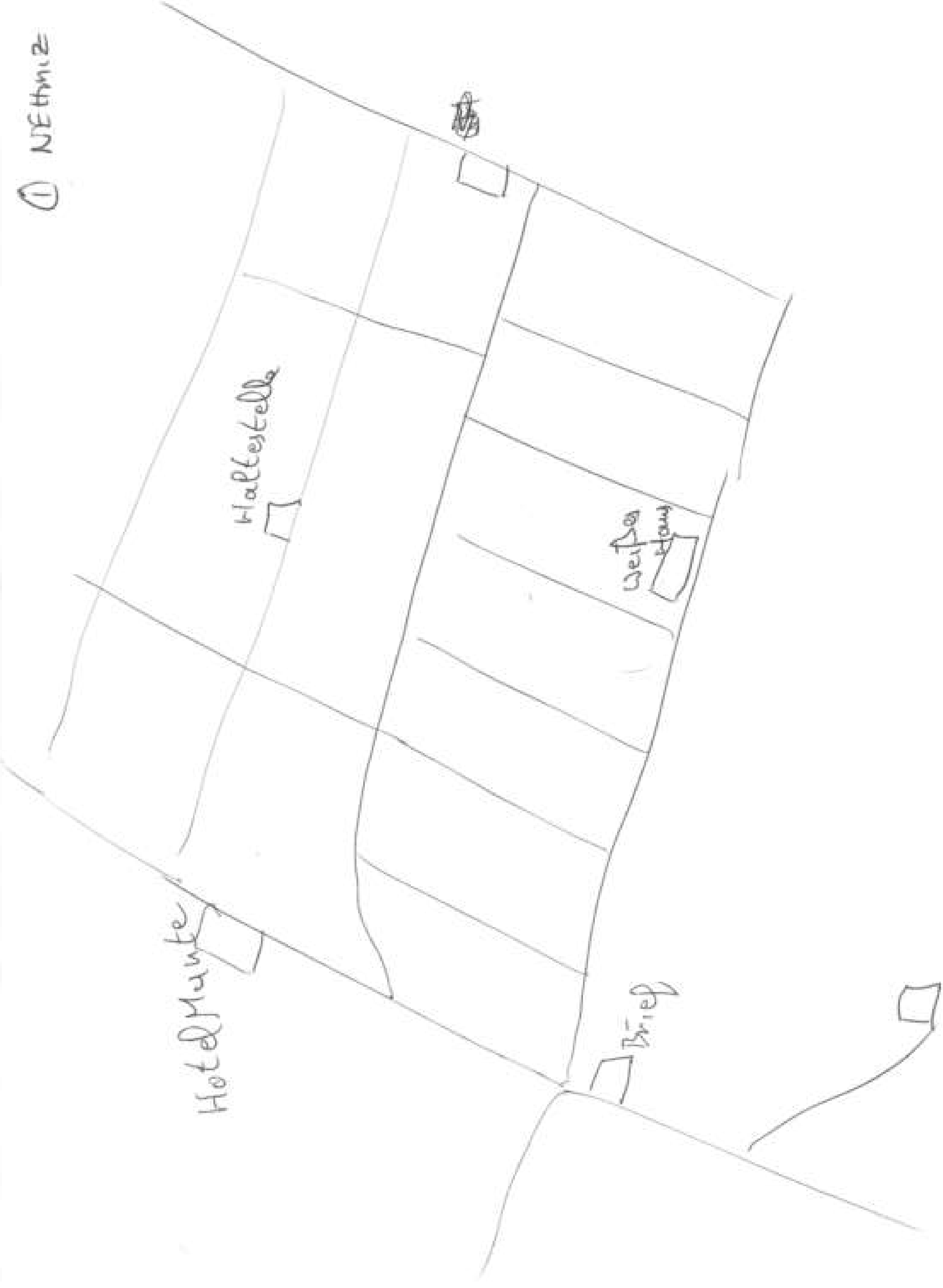

Gelbe Gebäude
Weißes Haus
Bushaltestelle
Briefkasten
Sport Eingang
Bank
Hotel
Wohnhaus

① WISCHKA

Hotel
Bushaltestelle
Gebäude
Wohnhaus
Bank
Weisses Haus
Gelbes Haus Gebäude
Briefkasten
Eingang Sportzentrum

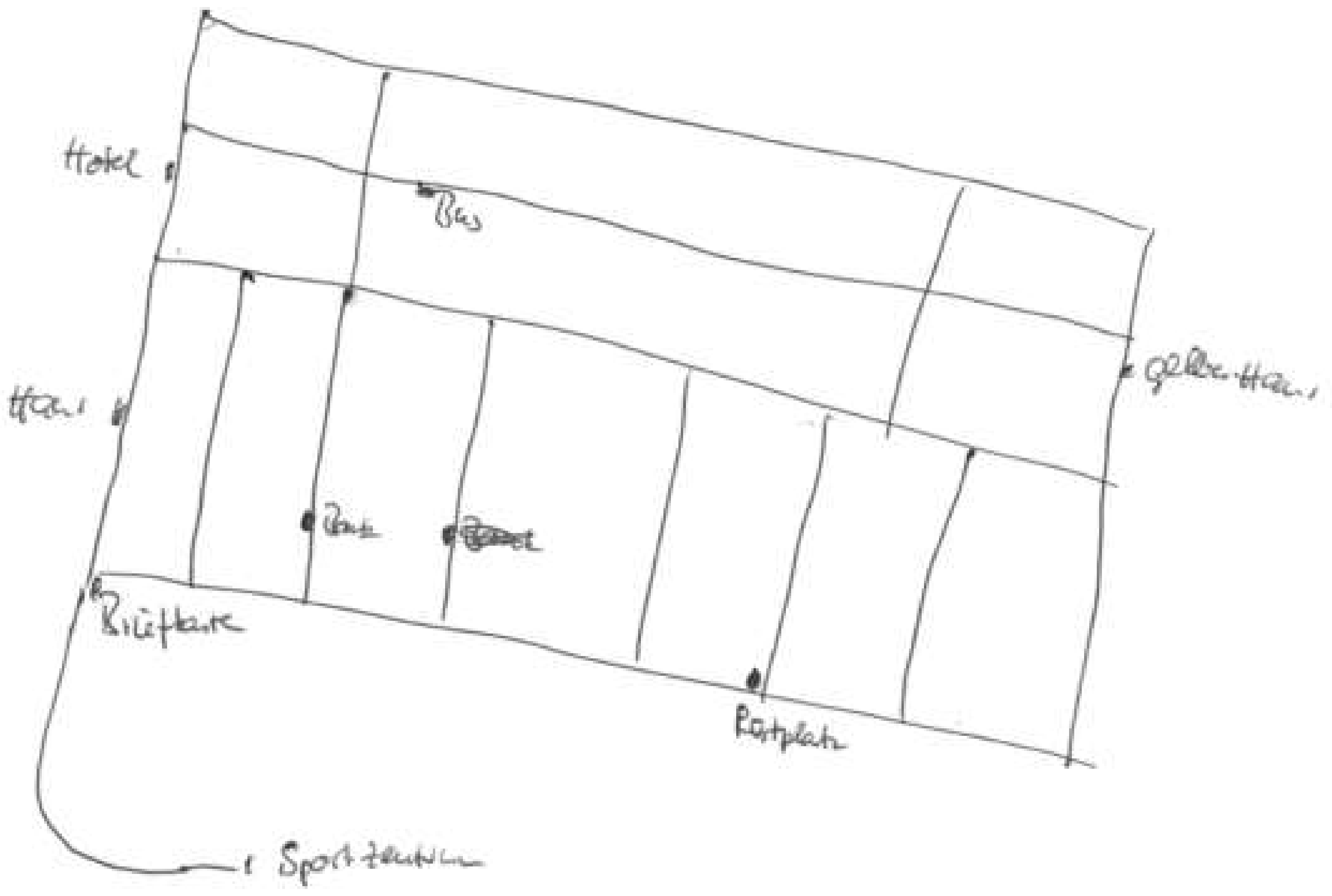

① KAPPERMAN


① SCHULTZ
Bus
Briefkasten
Bank
Wohnhaus
Sportzentrum

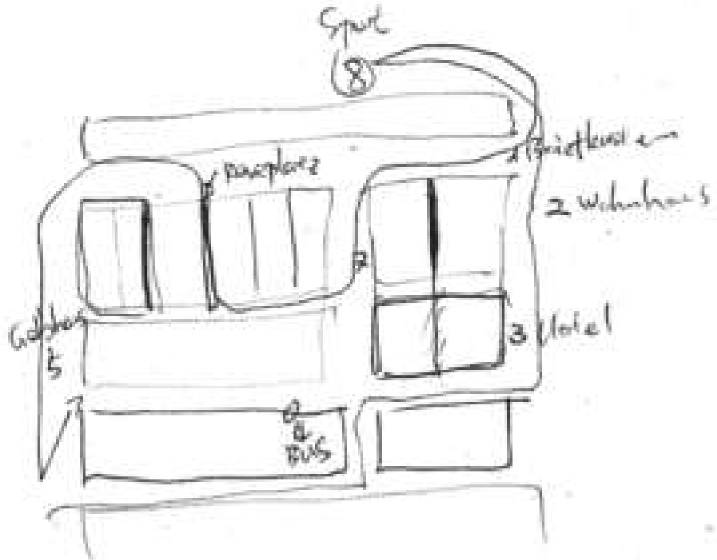


① NEthniz
Haltestelle
Hotel Munte
Weißes Haus
Brief

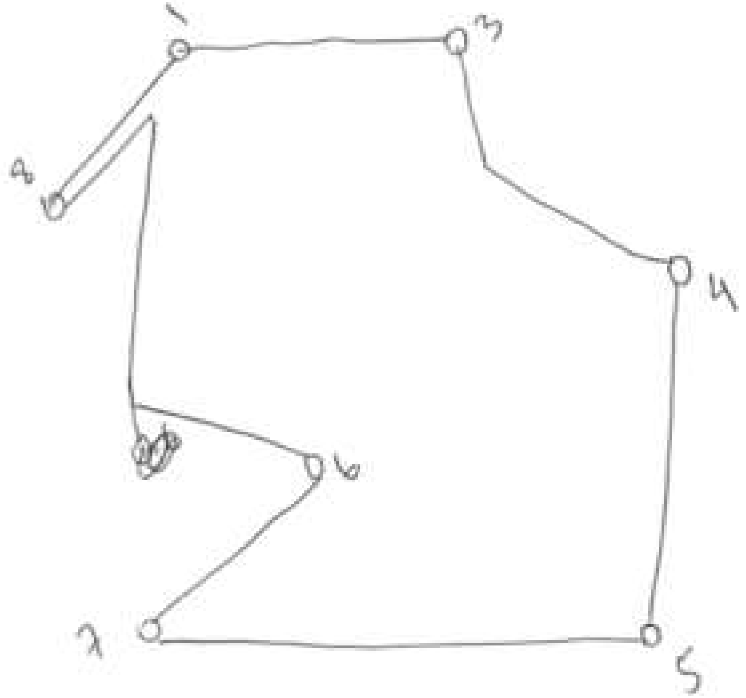
② Neugebaum

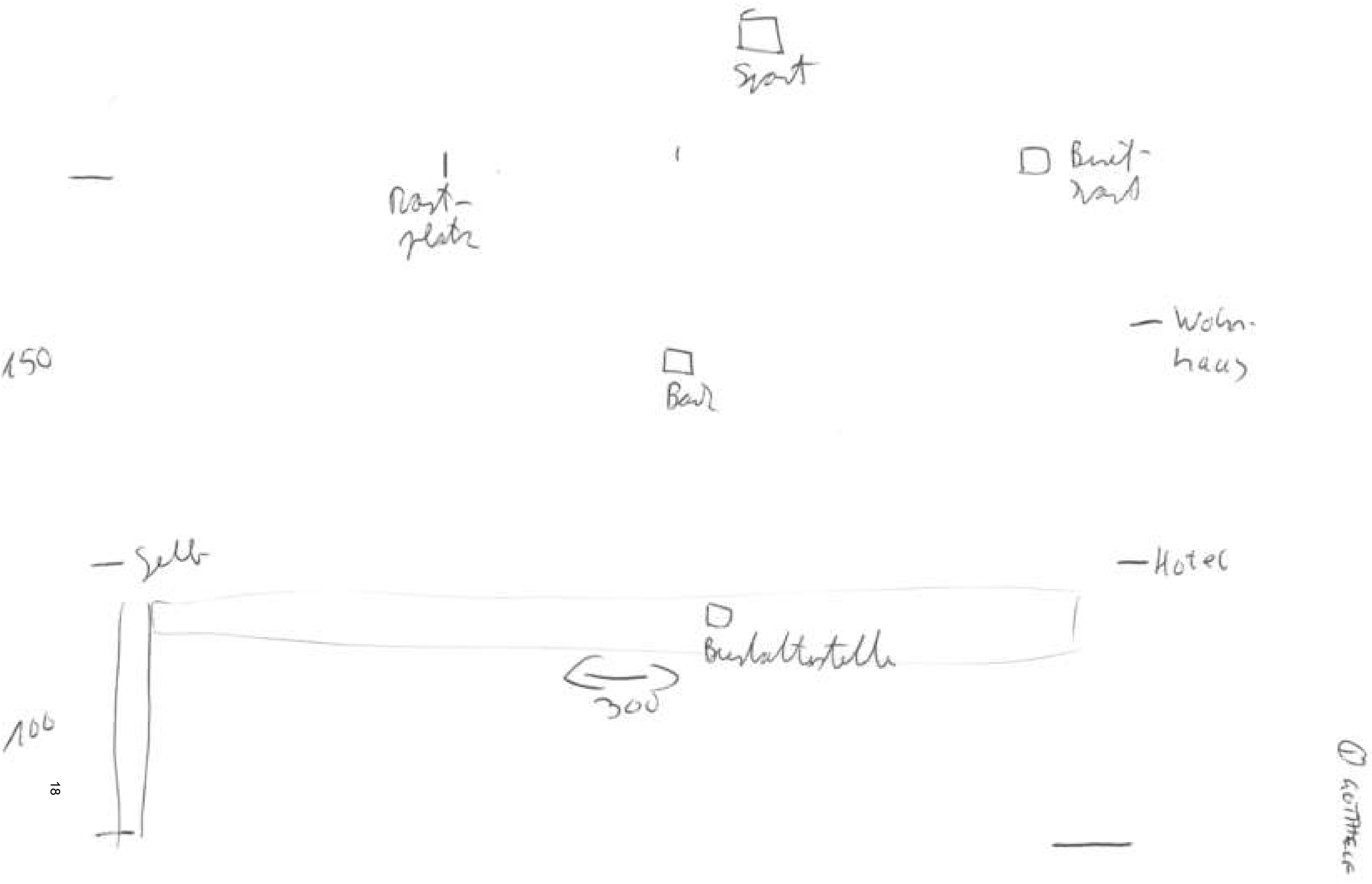

Hotel
Bus
Haus
Bank
Briefkasten
gelbes Haus
Rastplatz
Sportzentrum

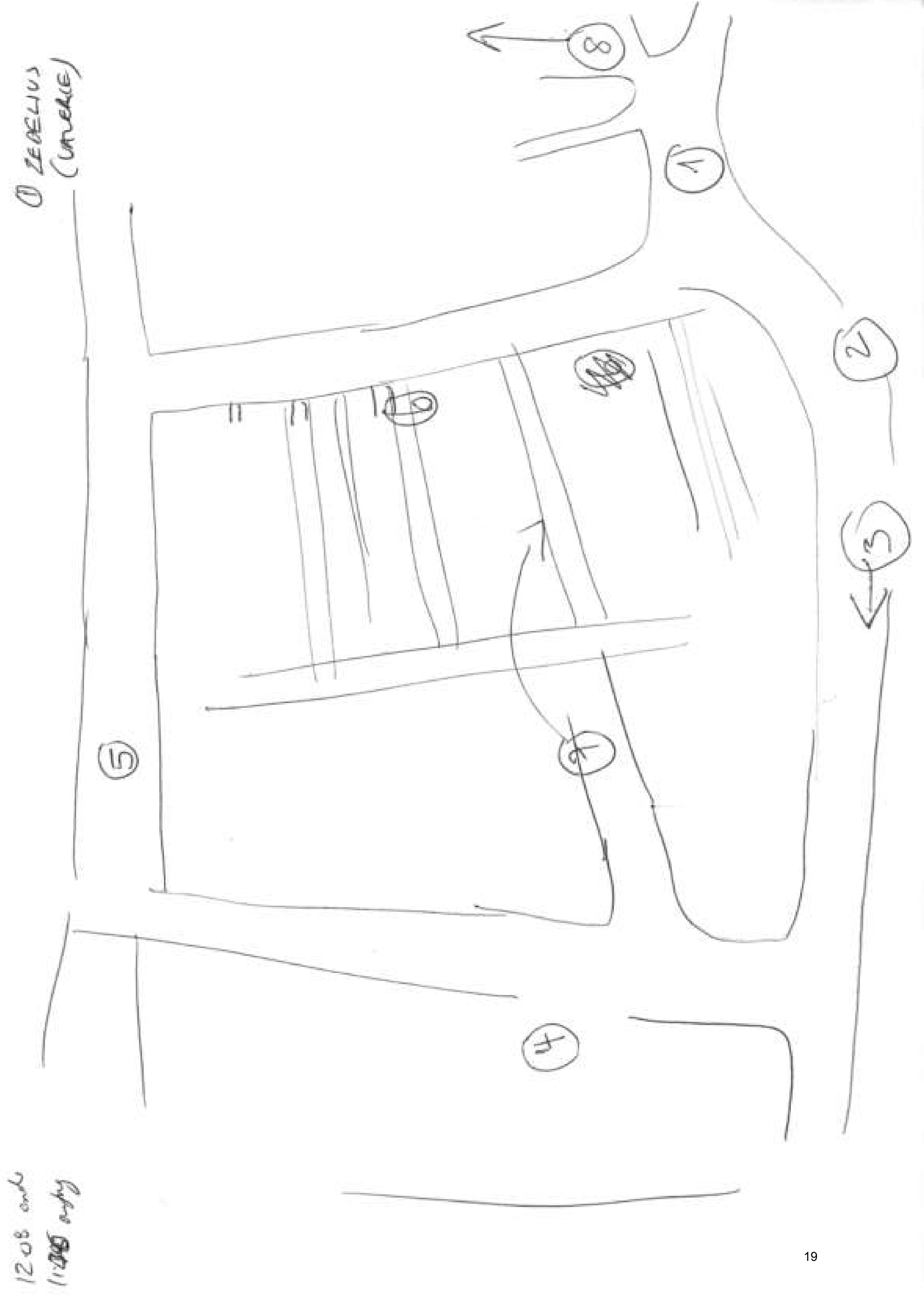
CHEN ①

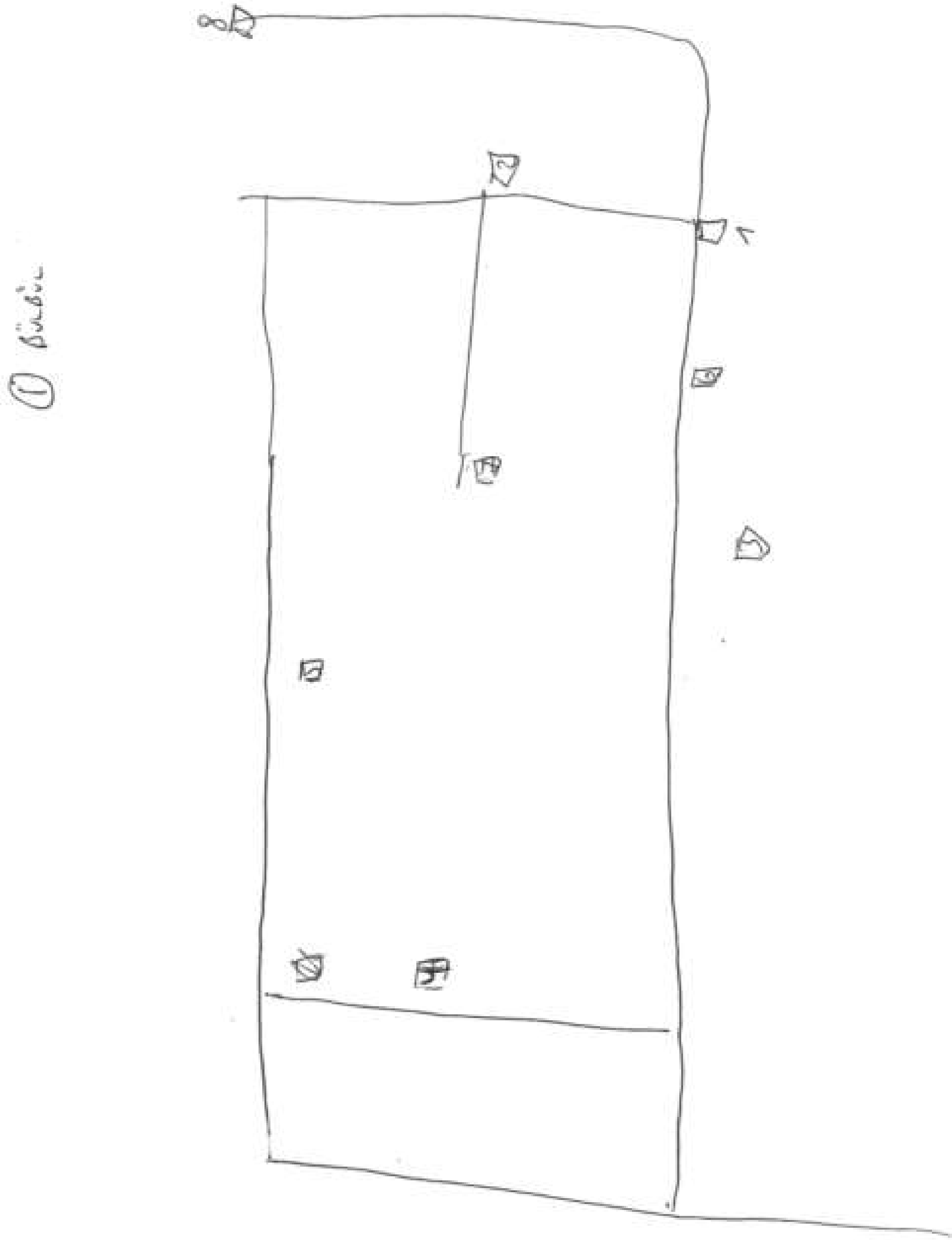


Salim ①

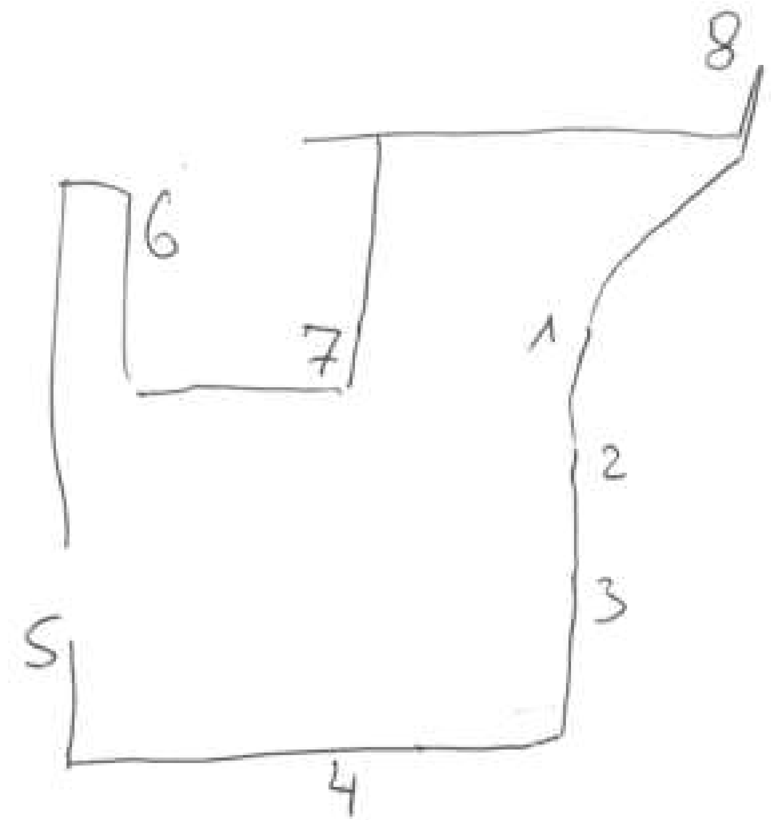



Sport
Rastplatz
Bar
Wohnhaus
Hotel
Bushaltestelle
300
150
100
1 GOTTHELF


① ZEDELIUS
(UNMARKED)
12 08 only



① schnitt



(8) Eingang Sportzentrum

(6) Depes Haus

(1) Briefkasten

(2) Wohnhaus

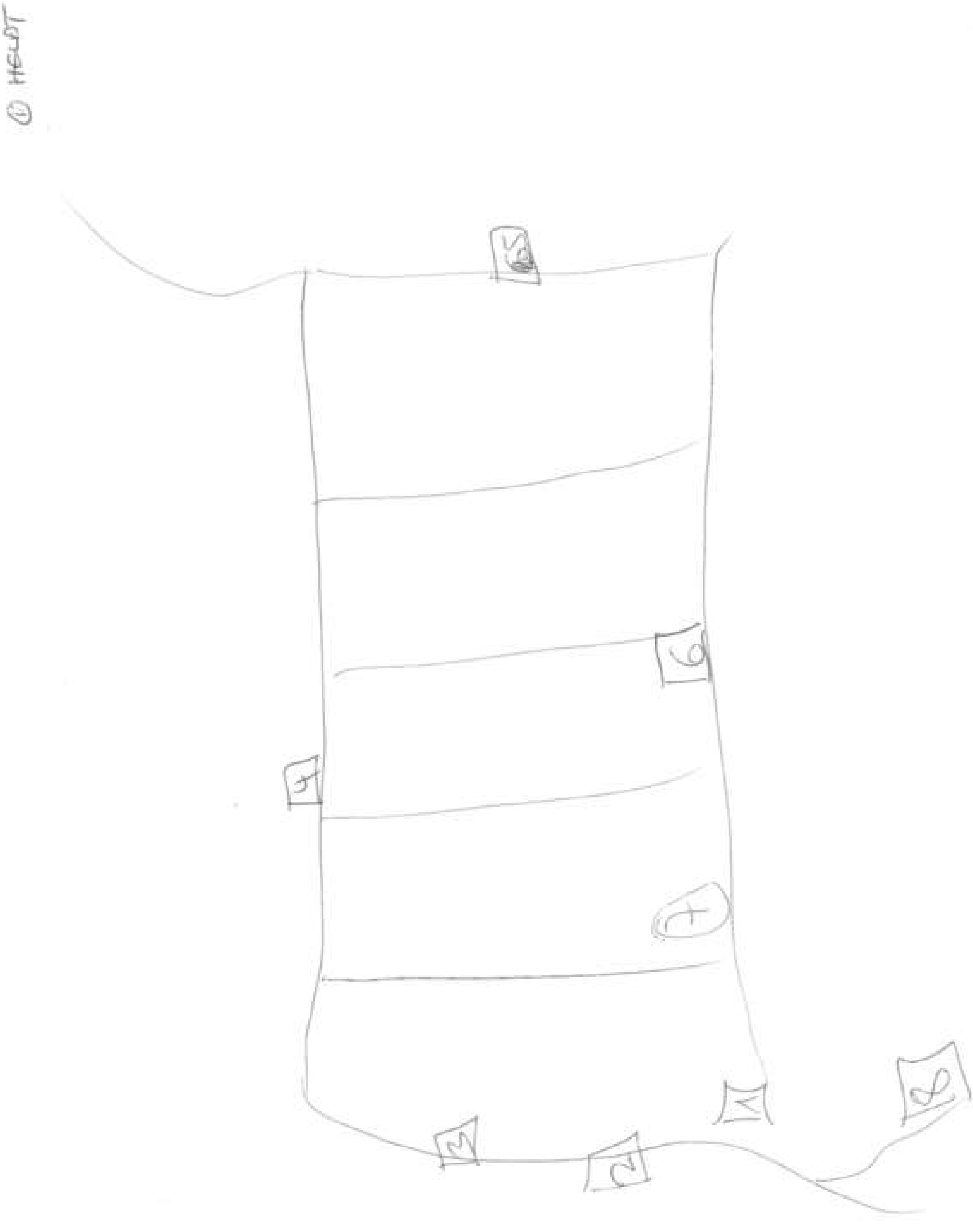
(7) Bank

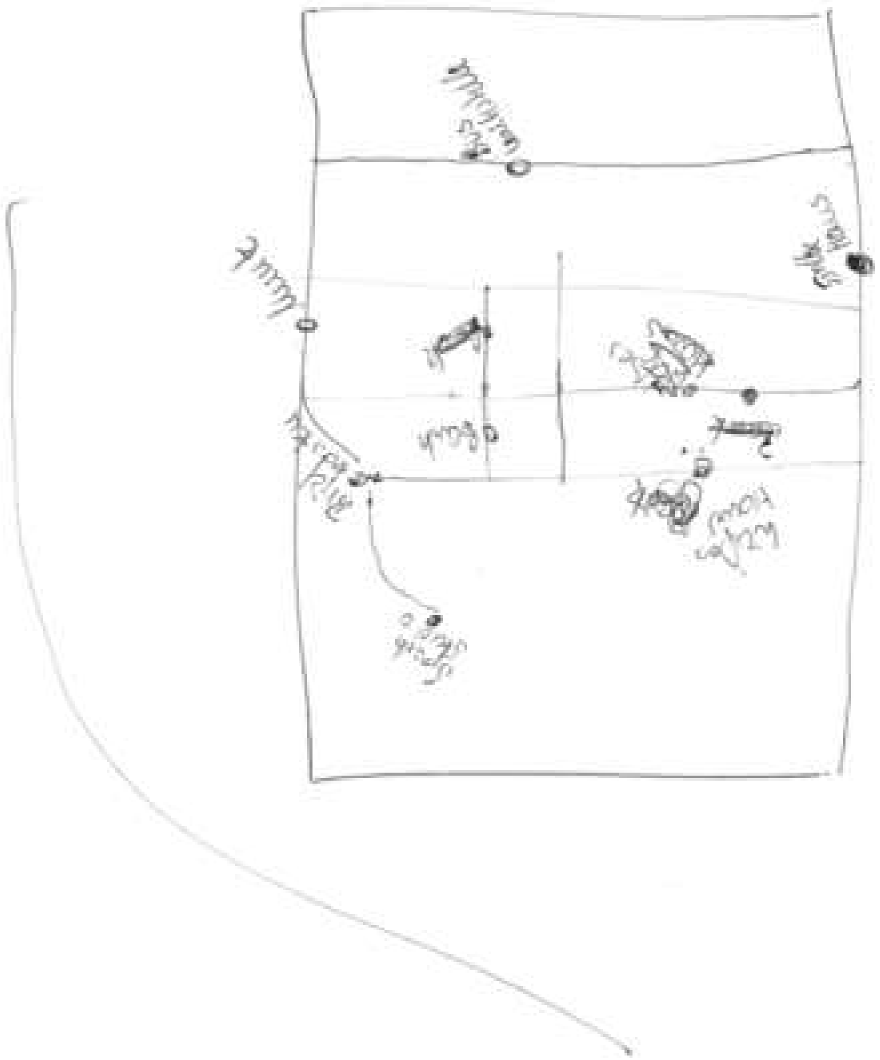
(3) Hotel Munte

(5) gelbes Gebäude

(4) Bushaltestelle

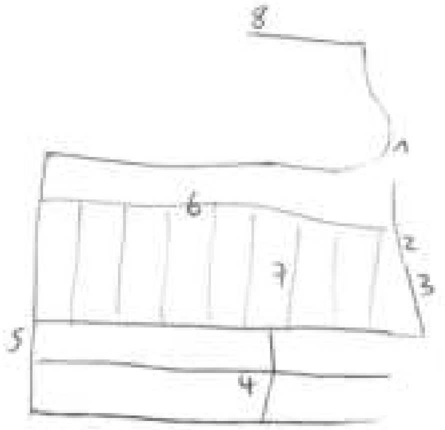
(1) TESSMANN


1
2
3
4
6
7
8



① MARKOUSKA

① FNICEN



(6)

(7) (8)

(5)

Appendix C-2

Empirical Study One: Qualitative representations of Cognitive Map data

Results for Individual Destinations

Post Box:	Distance in metres from real location
avg (mobile)	60.8
avg (map)	79.5

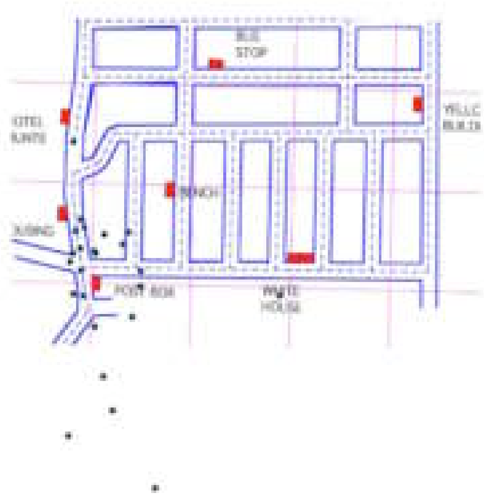


Fig C-2.1. Accuracy of Participants Cognitive Maps for destination Post Box

Housing	Distance in metres from real location
avg (mobile)	48.8
avg (map)	61

Fig C-2.2. Accuracy of Participants Cognitive Maps for destination Housing

Hotel	Distance in metres from real location
avg (mobile)	38.6
avg (map)	137

Fig C-2.3. Accuracy of Participants Cognitive Maps for destination Hotel

Bus Stop	Distance in metres from real location
avg (mobile)	97.4
avg (map)	150.9

Fig C-2.4. Accuracy of Participants Cognitive Maps for destination Bus Stop

Yellow Building	Distance in metres from real location
avg (mobile)	127.5
avg (map)	127.6

Fig C-2.5. Accuracy of Participants Cognitive Maps for destination Yellow Building

White House	Distance in metres from real location
avg (mobile)	108.7
avg (map)	107.6

Fig C-2.6 Accuracy of Participants Cognitive Maps for destination White House

Bench	Distance in metres from real location
avg (mobile)	85.4
avg (map)	71

Fig C-2.7. Accuracy of Participants Cognitive Maps for destination Bench

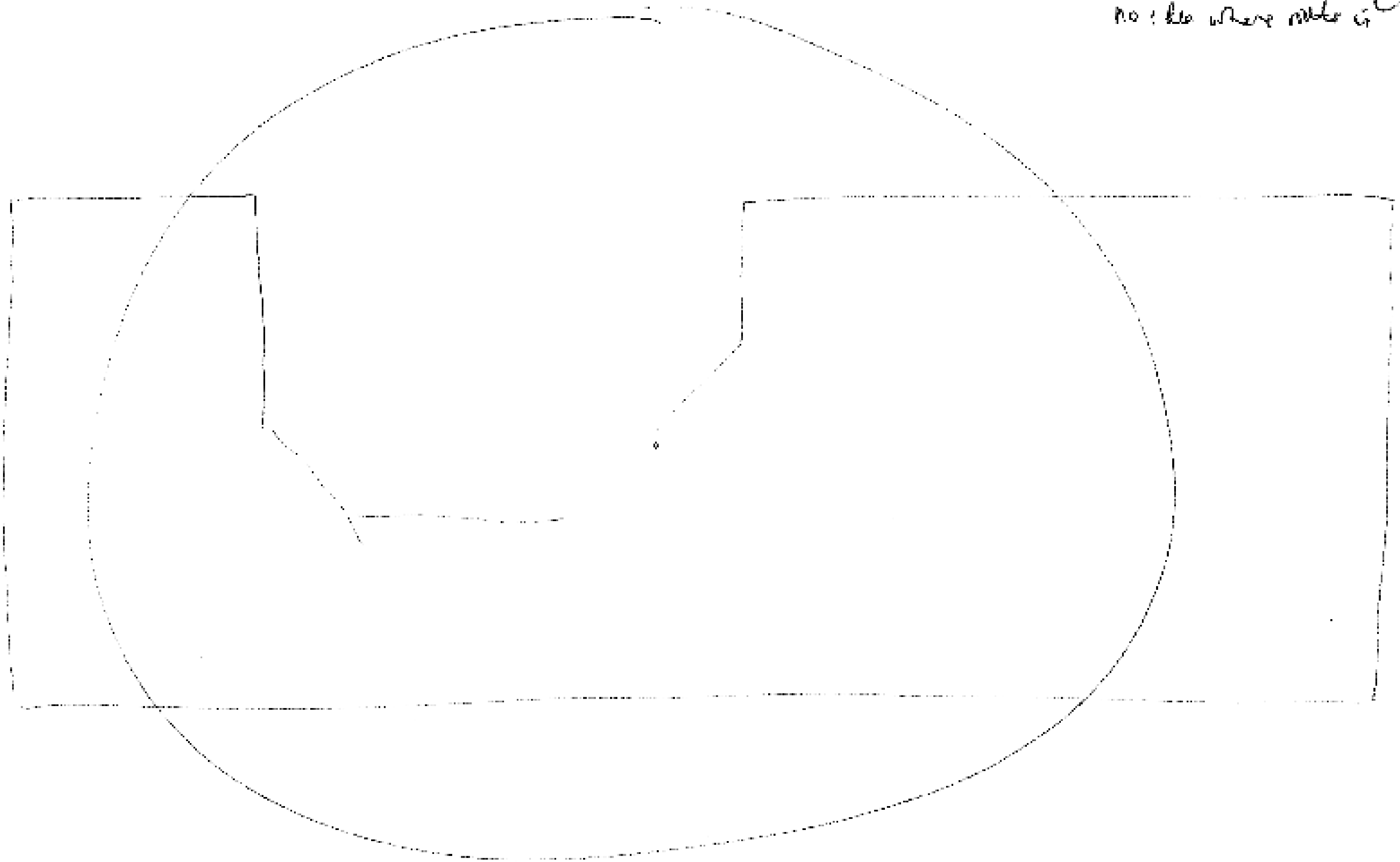
Sports Centre	Distance in metres from real location
avg (mobile)	38.6
avg (map)	137

Fig C-2.8 Accuracy of Participants Cognitive Maps for destination Sports Centre

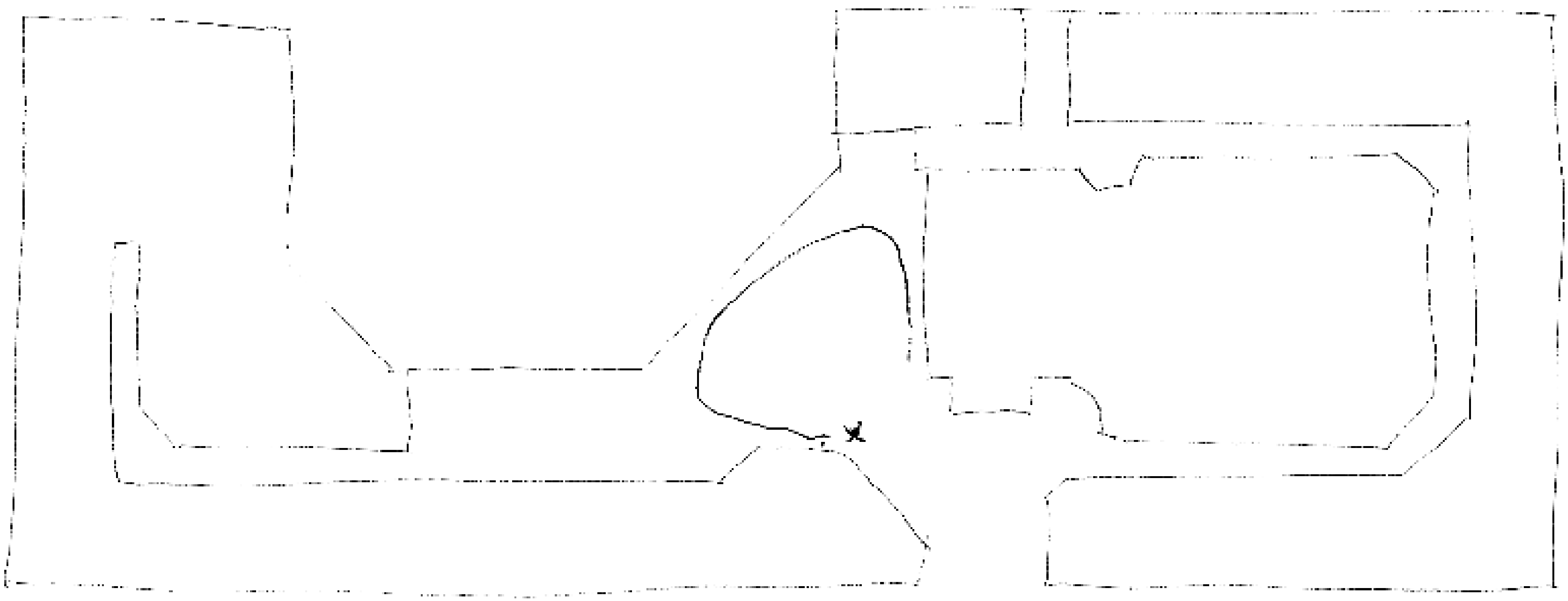
Appendix D-1

Empirical Study Two: Participants' sktech maps

3/10/07 BECKER.
no idea where mole is (M)



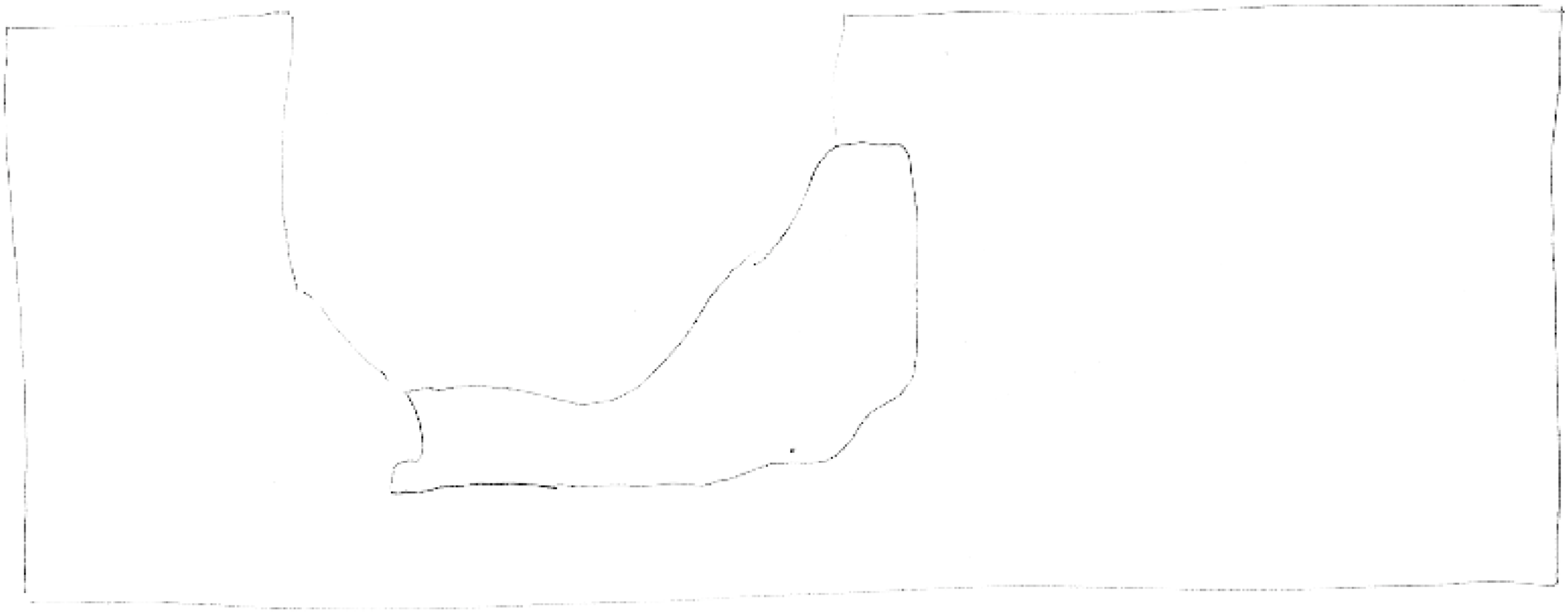
2/10/07 CARBALLO



3/10/02 CHI

PG1 (F)

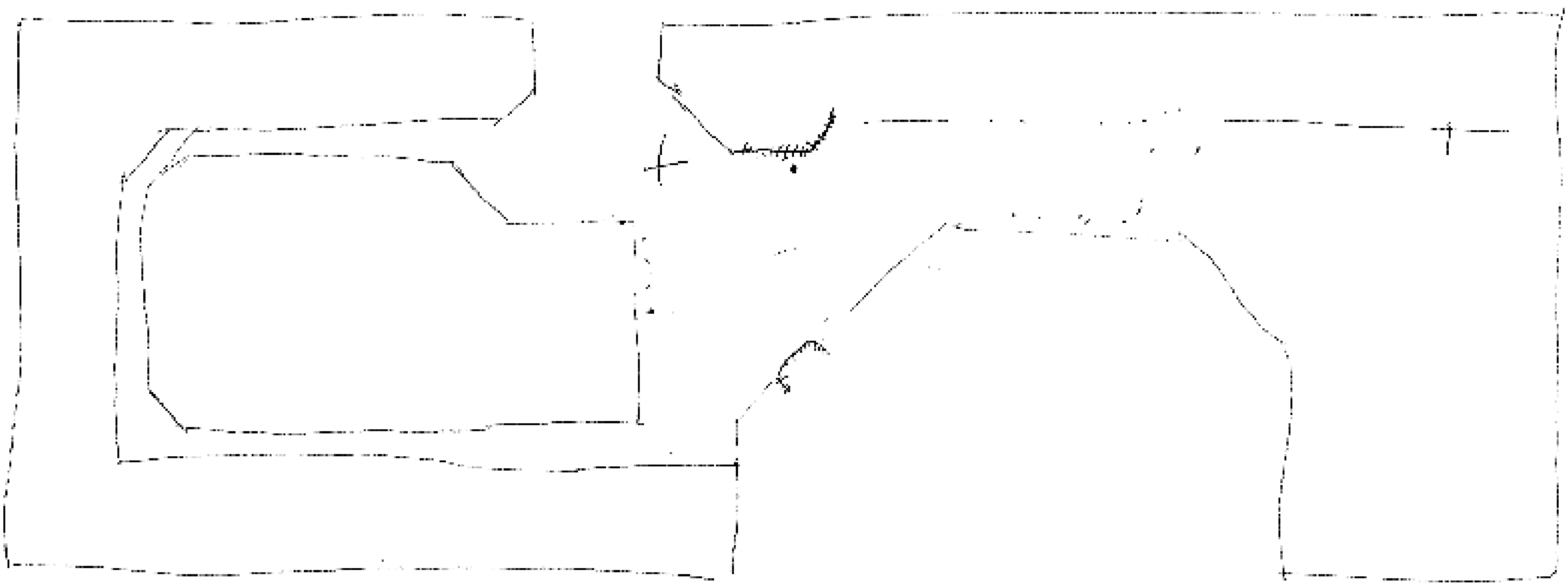
GROUND FLOOR



- can get it in middle of cafe
- may be in canyon, but like nature trail
- asked for upstairs plan

2/10/07 CLOUPA (F)

30 mins but returned for another 1 hour



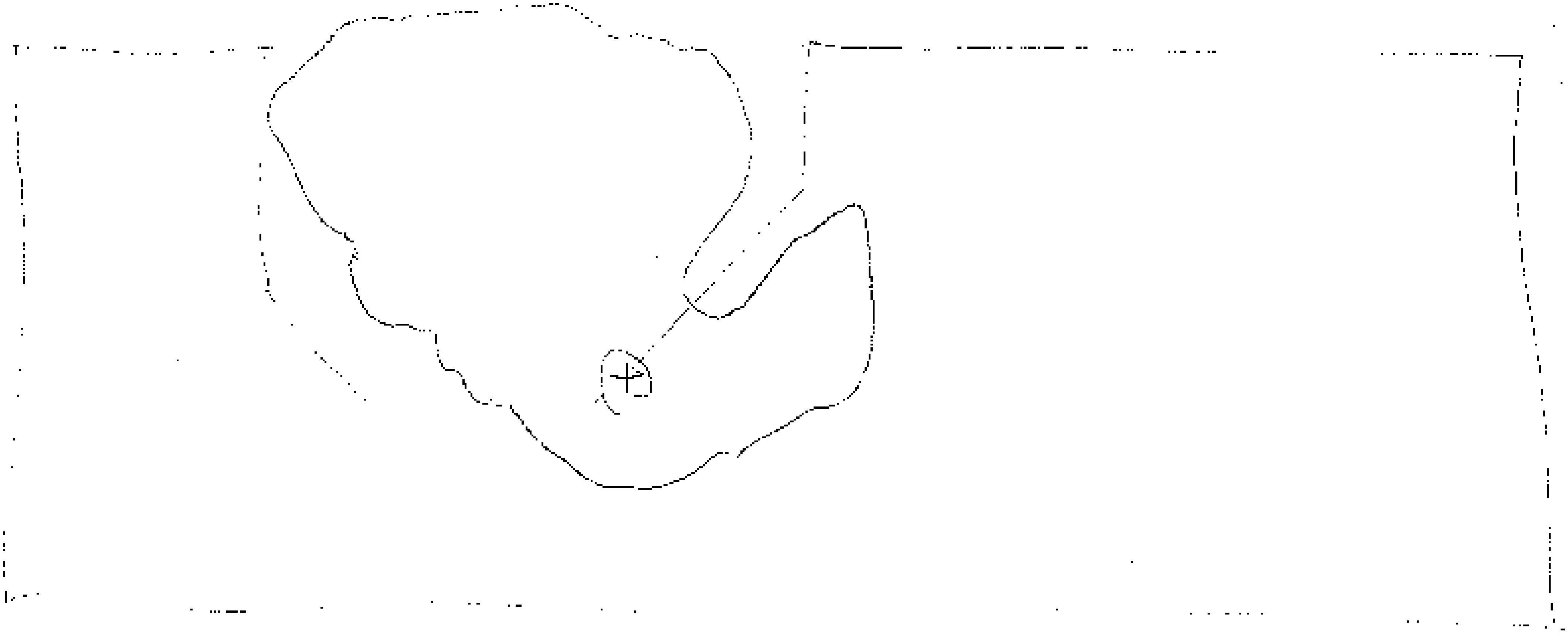
- very nice overall

not sure about taking the space - dotted line

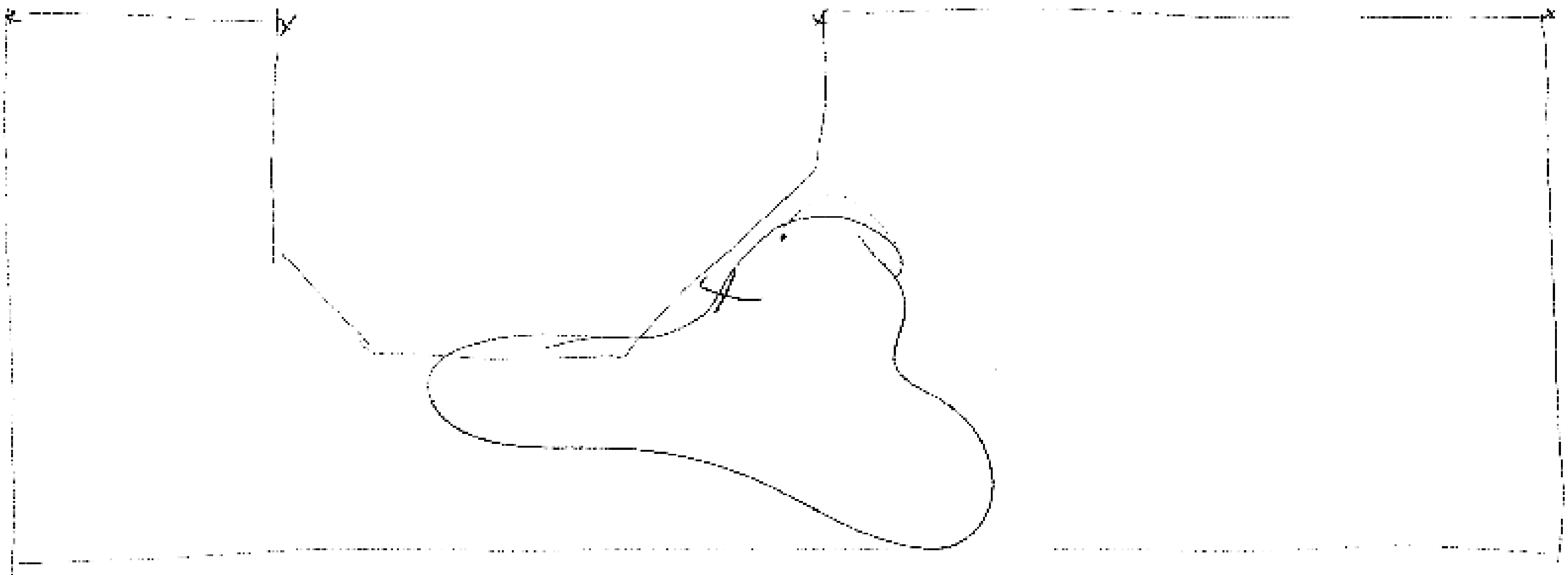
only knows where she sits

3/10/07 DR MARK

wasn't sure [illegible] edge [illegible]
[illegible] was [illegible] or [illegible]
- only knows because [illegible]
summer

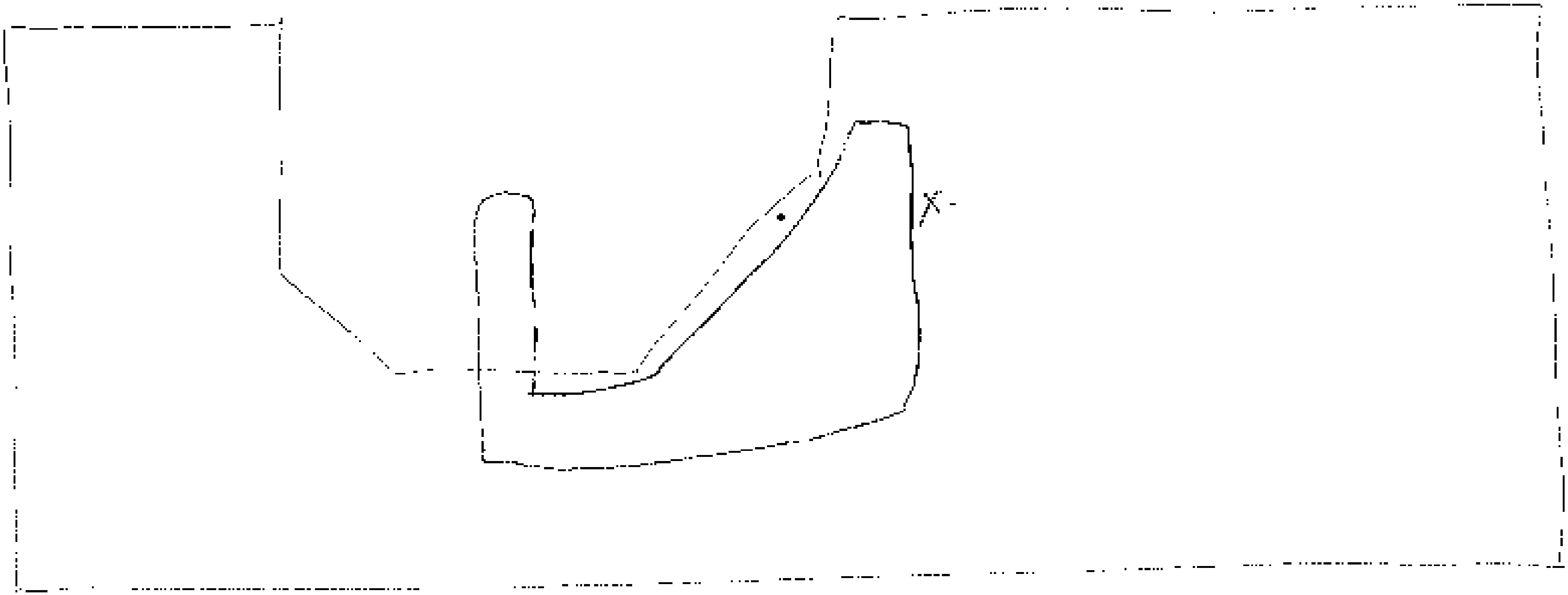


3/10/07 M.AN 1

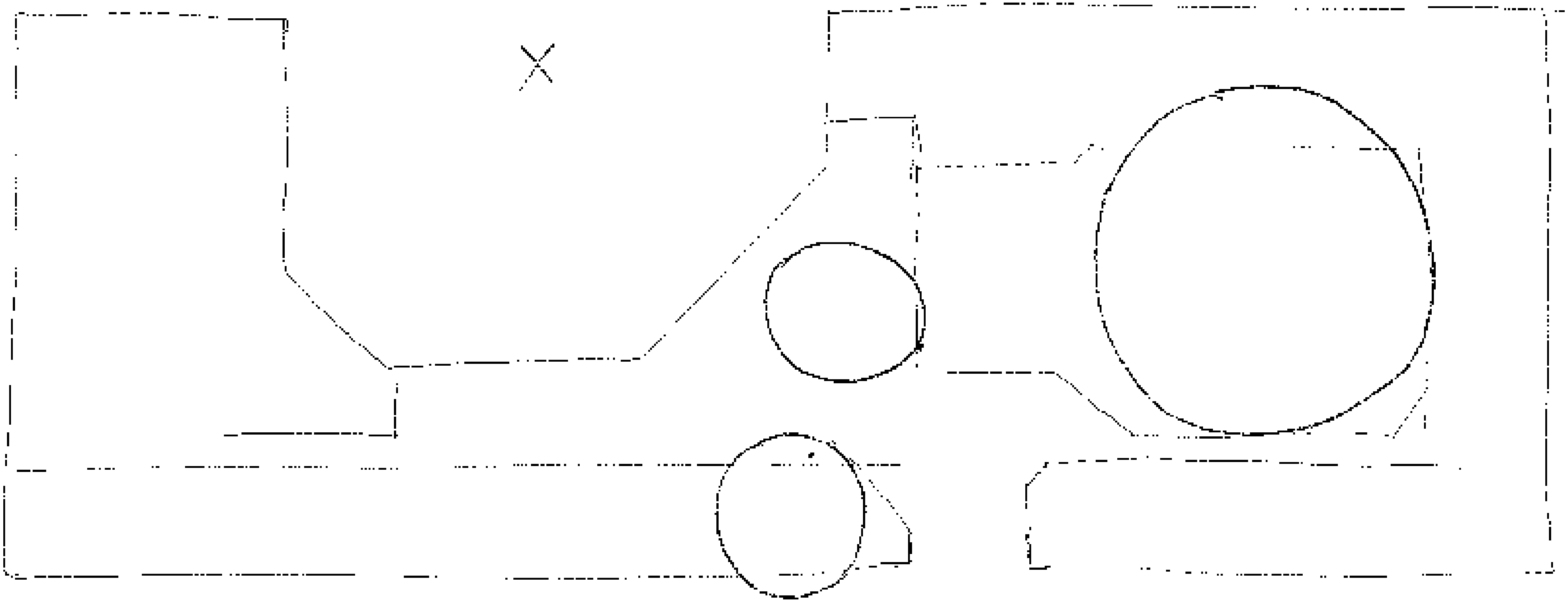


3/10/07 M#W 2 (iv)

- has used aferesis (?) here, but can't (?) see thing sometimes
- (?) about (?) cafe seeing



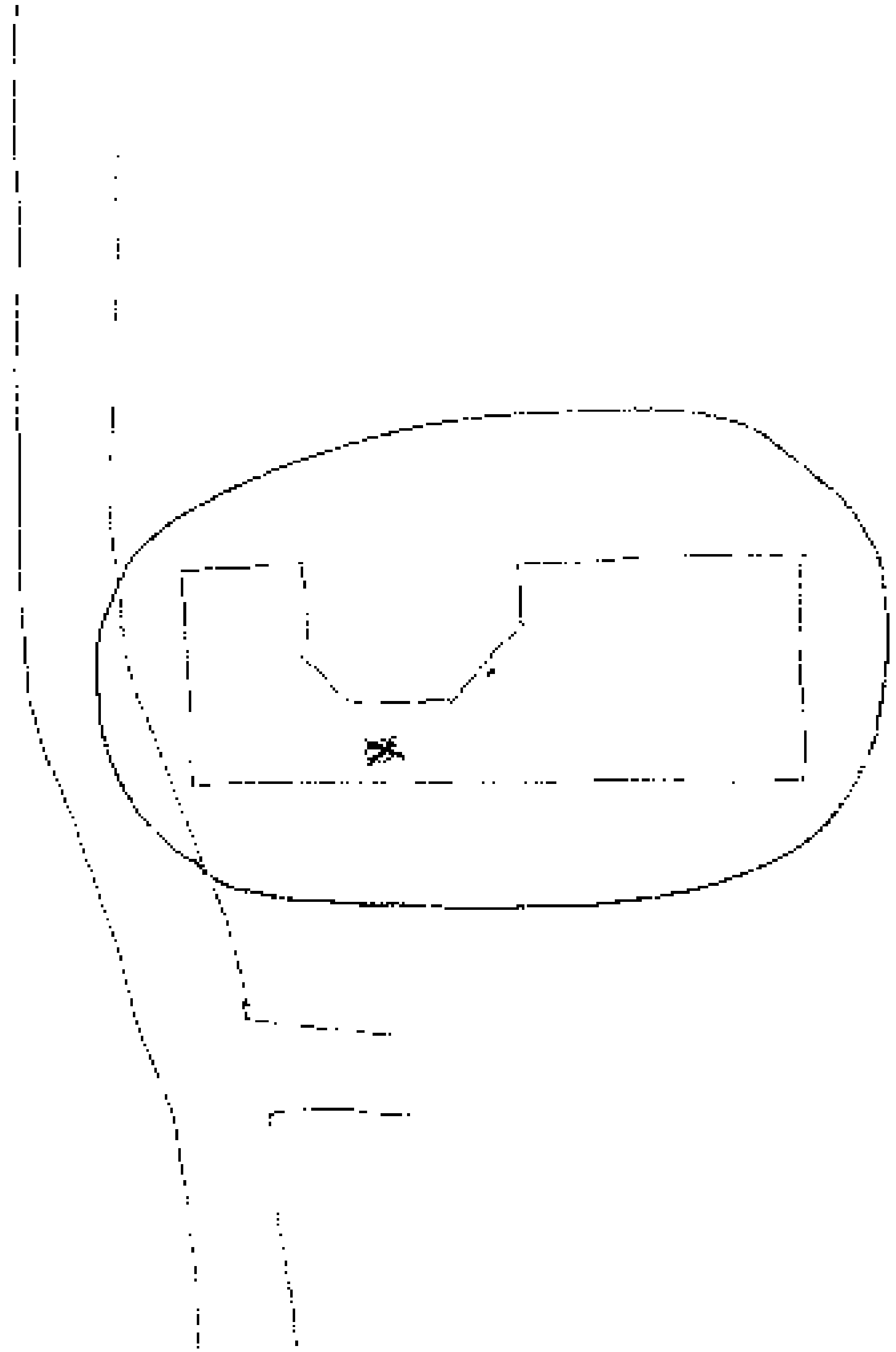
1/10/07 MEDON
3... (E)



1/10/07 STACEY (F)

MAP 2

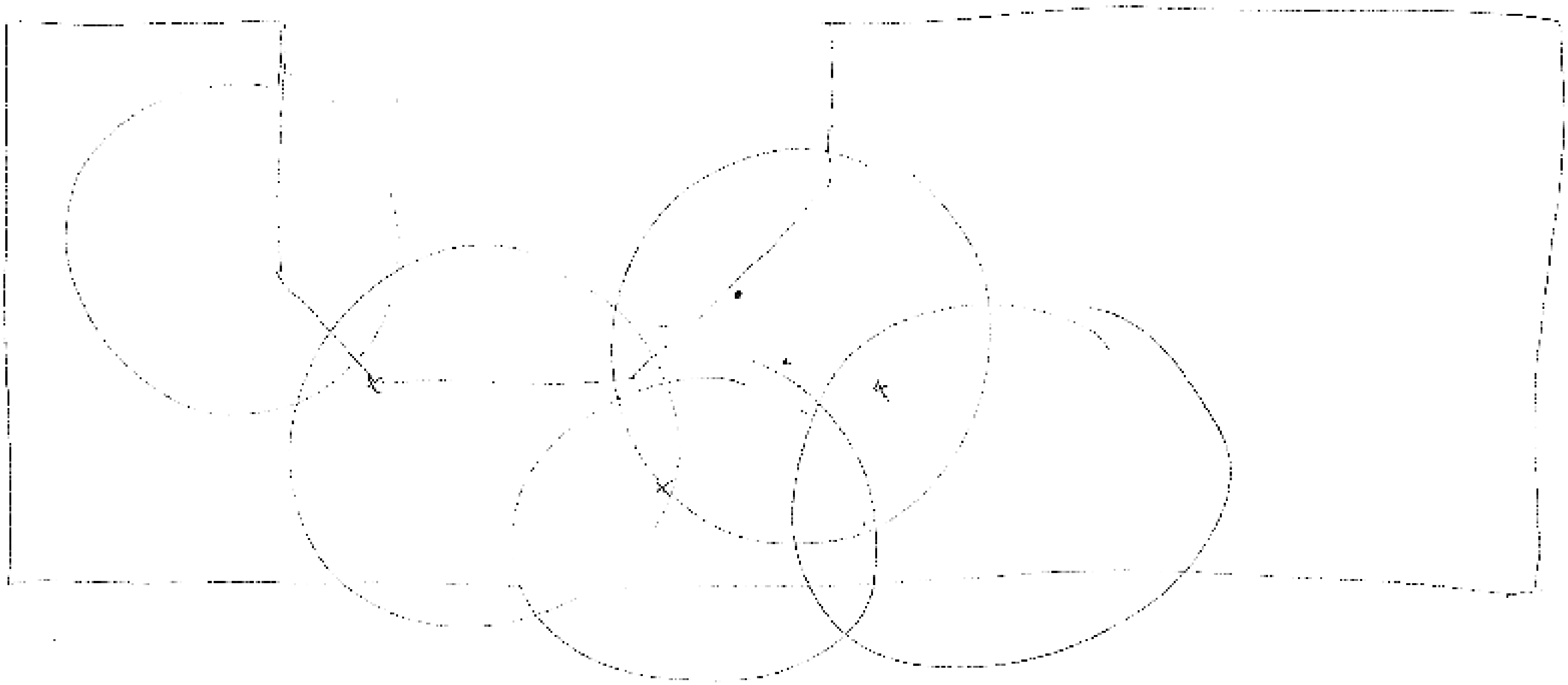
1 hour



3/10/07

SANDERS (m)

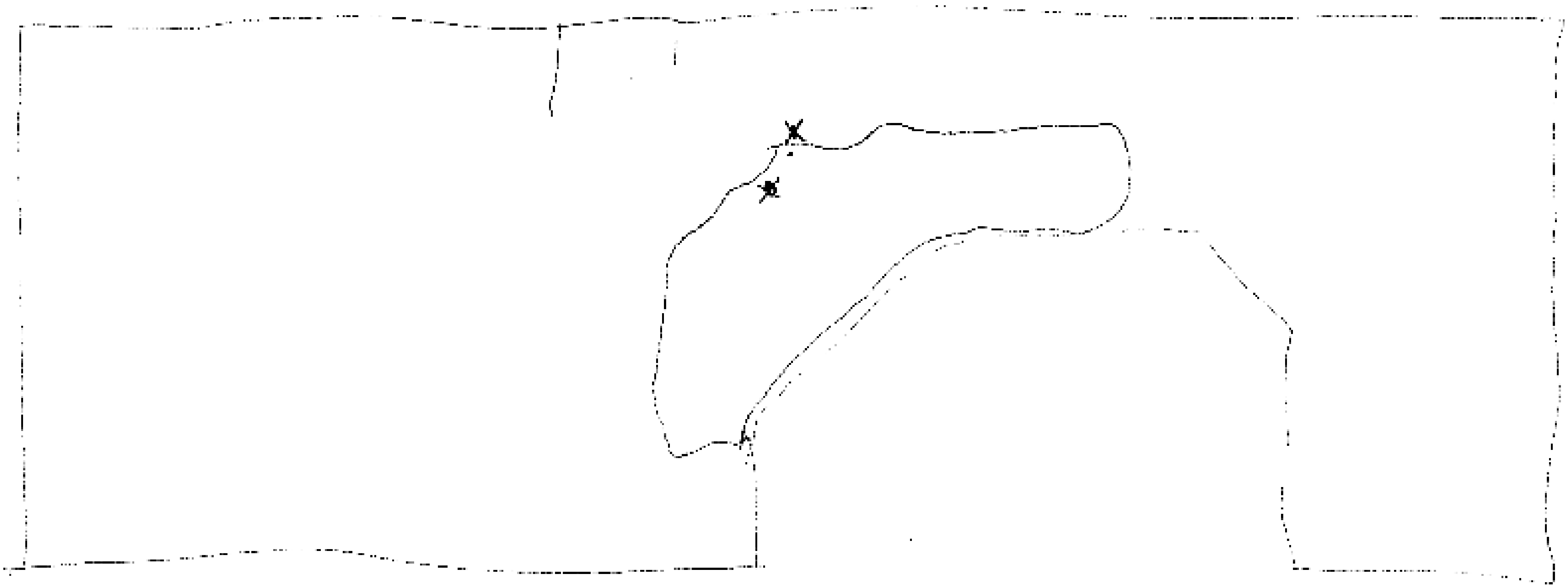
no interest access; but has that line



2/10/07

SAN MINA
30 mins
but returned

(F)



— was empty, so this is where she went — via print gallery (oriental connection)
— maybe get a cam in hall, but no seats so not walked
· Albany afo room Something and has to go via courtyard and get swindled
· saw couches being moved from the west room

Appendix D-2

Empirical Study Two: WiFi usage over specific time period

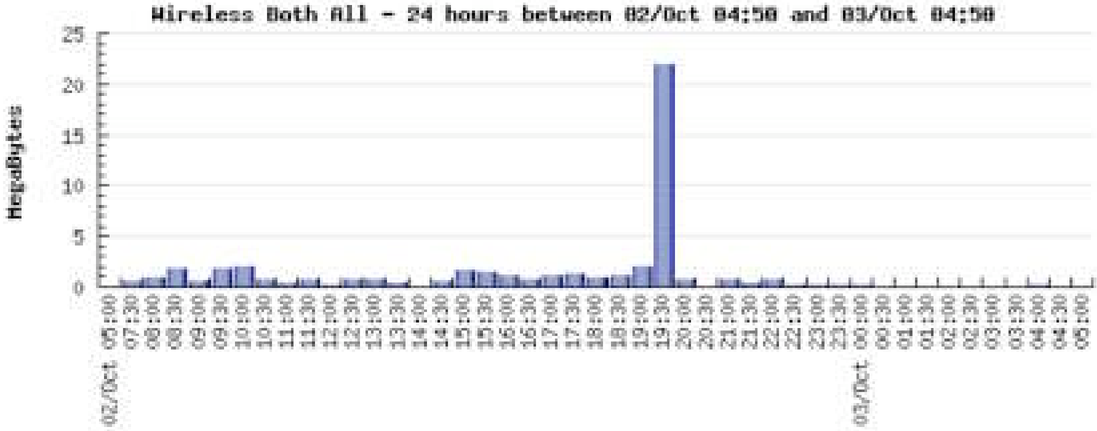


Fig D-2.1 WiFi node amusement
Location: Deptford Housing coop, located in roofspace of House 15 (10 storey high public housing block)

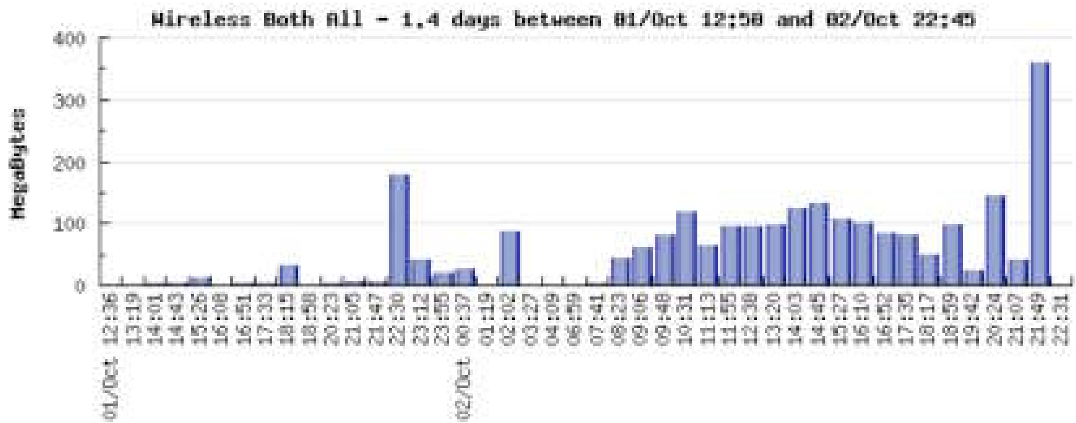


Fig D-2.2 WiFi node belief
Location: private house, 16 Holden house, Creekside (5 storey high public housing block)

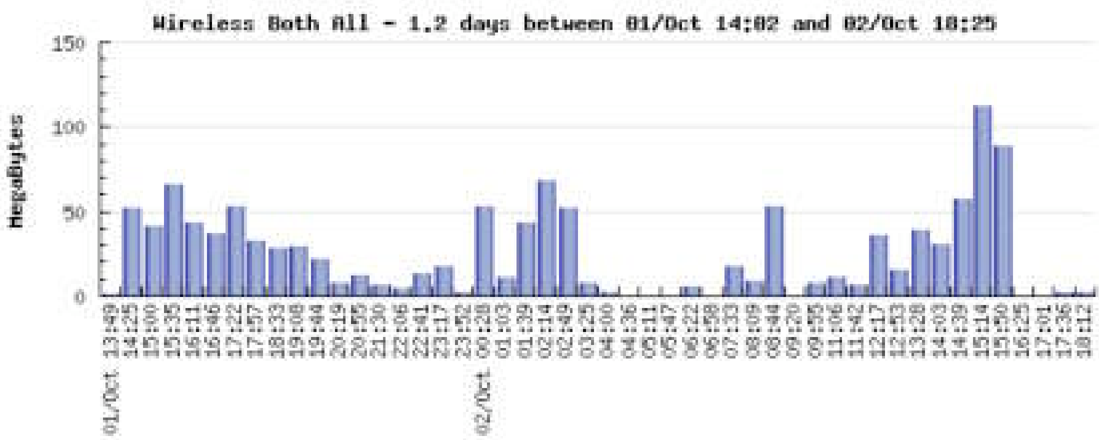


Fig D-2.3 WiFi node beauty
Location: private house, Deptford Church Street (private residential area)

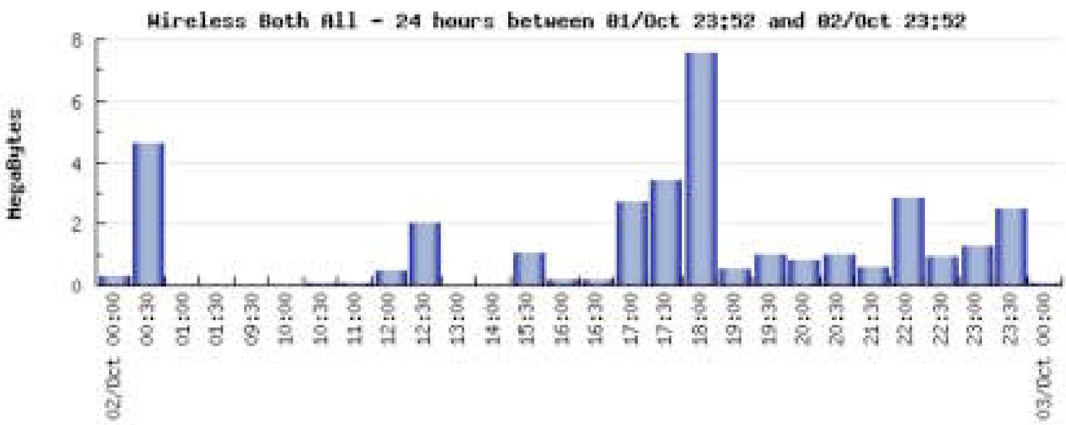


Fig D-2.4 WiFi node confidence
Location: Albury Street

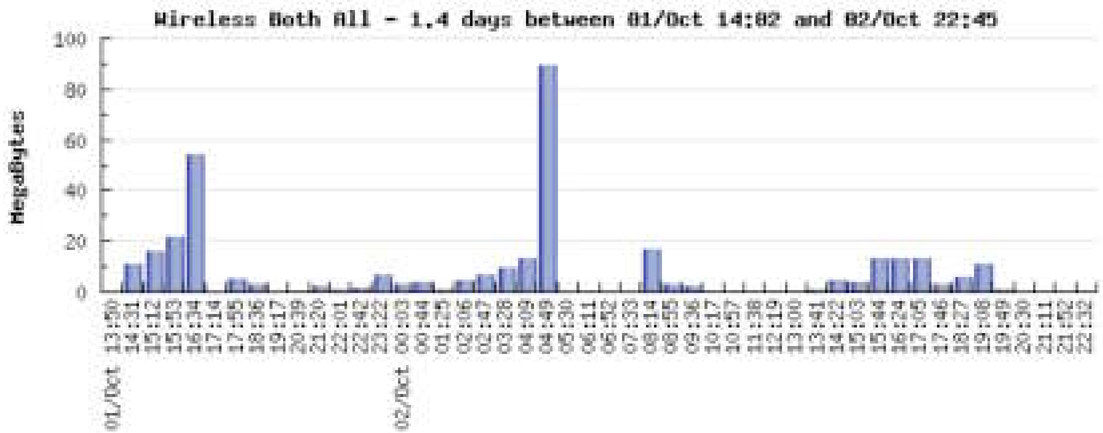


Fig D-2.5 WiFi node continuity
Location: Private arts centre, 6 Creekside

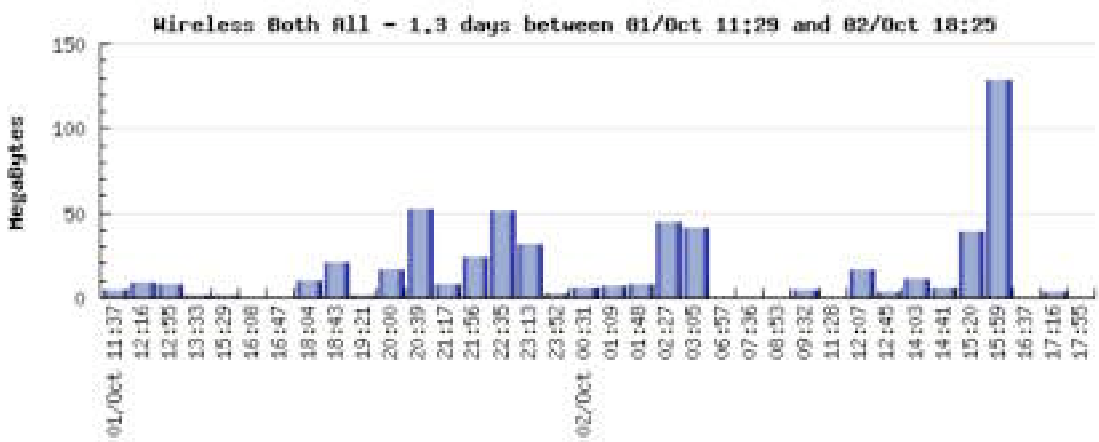


Fig D-2.6 WiFi node cows
Location: Giffin Street Business Centre (underneath railway arches)

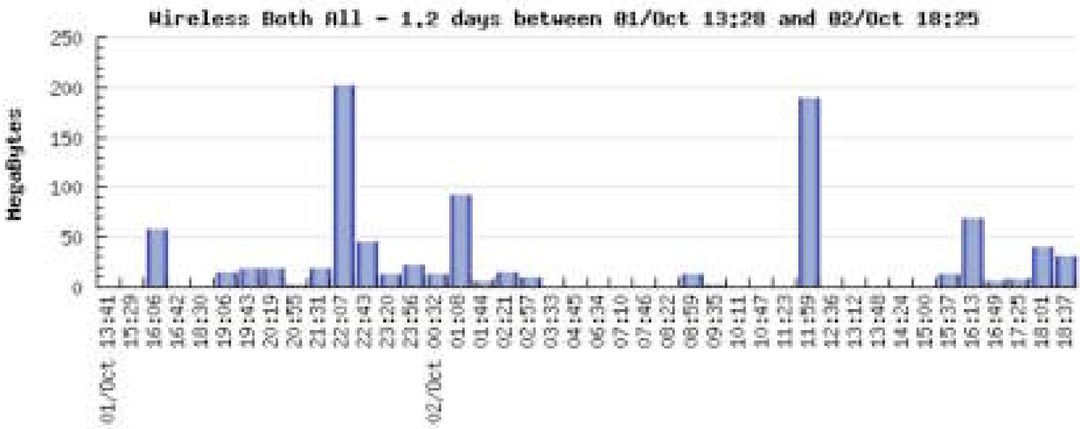


Fig D-2.7 WiFi node emotion
Location: Laban Centre, Creekside

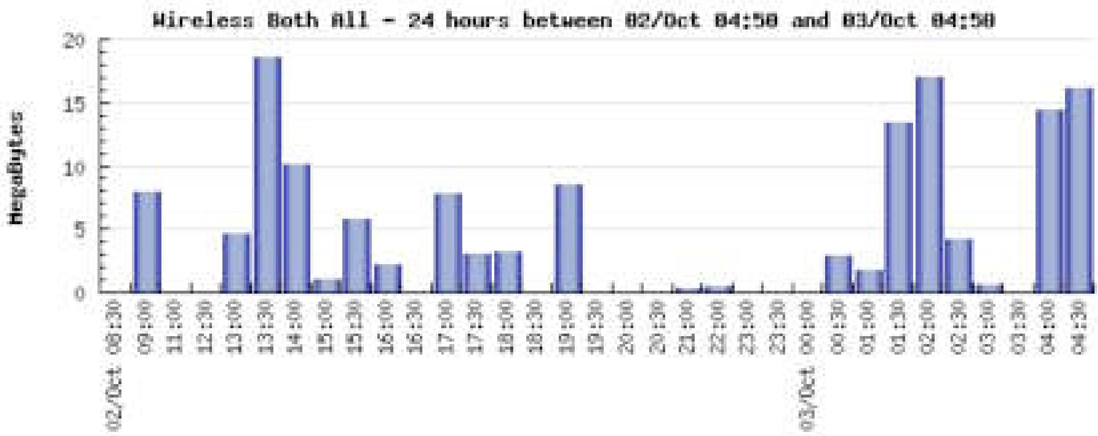


Fig D-2.8 WiFi node game
Location: Windsor Castle Public House, 161-163 Deptford High Street

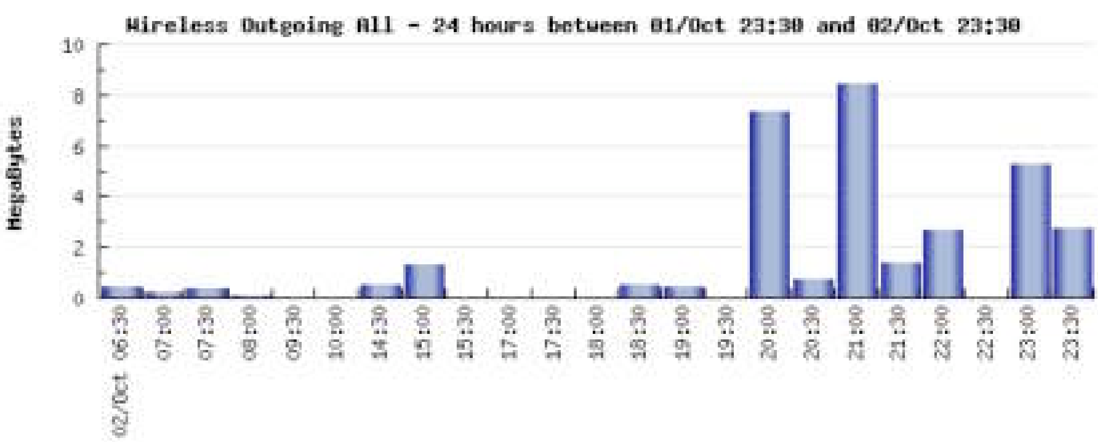


Fig D-2.9 WiFi node greed
Location: private residence, Giffin Street

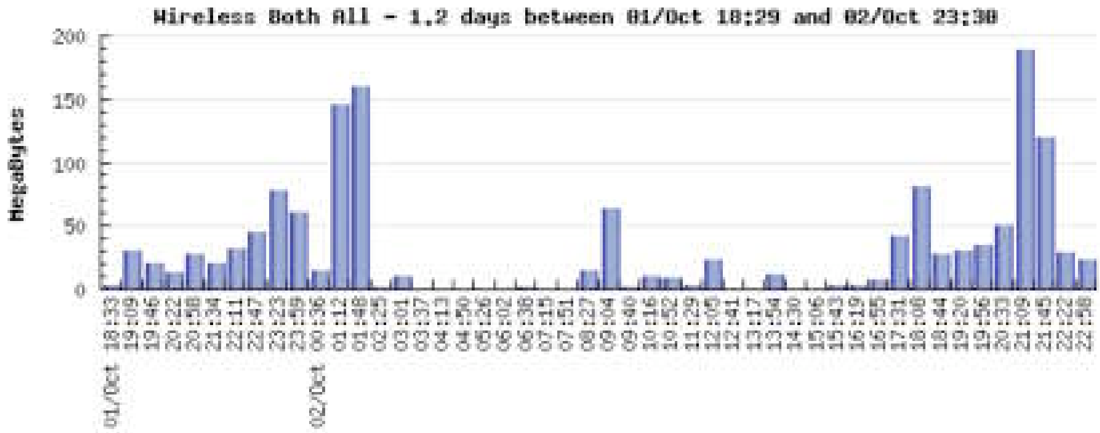


Fig D-2.10 WiFi node invention
Location: Deptford housing coop office, Idonia Street

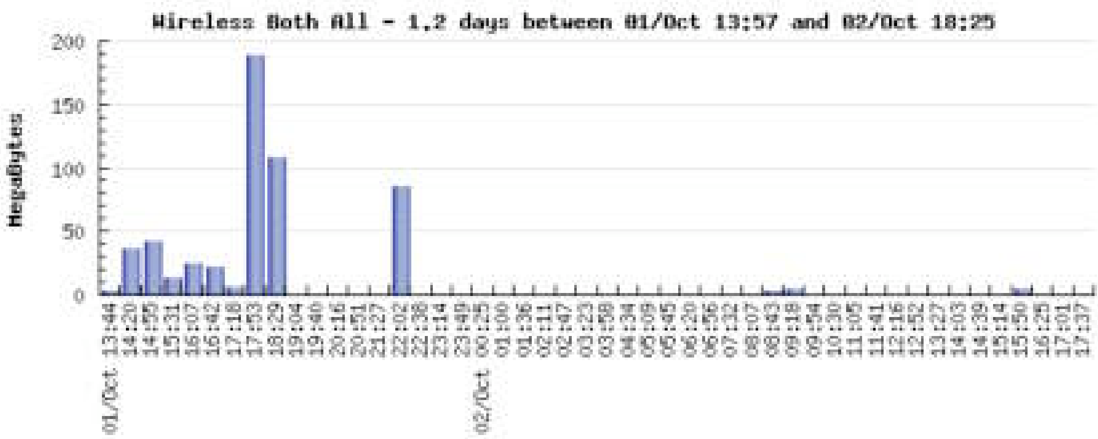


Fig D-2.11 WiFi node mudlarks
Location: Creekside Community Wildlife Centre, 14 Creekside (located next to business park)

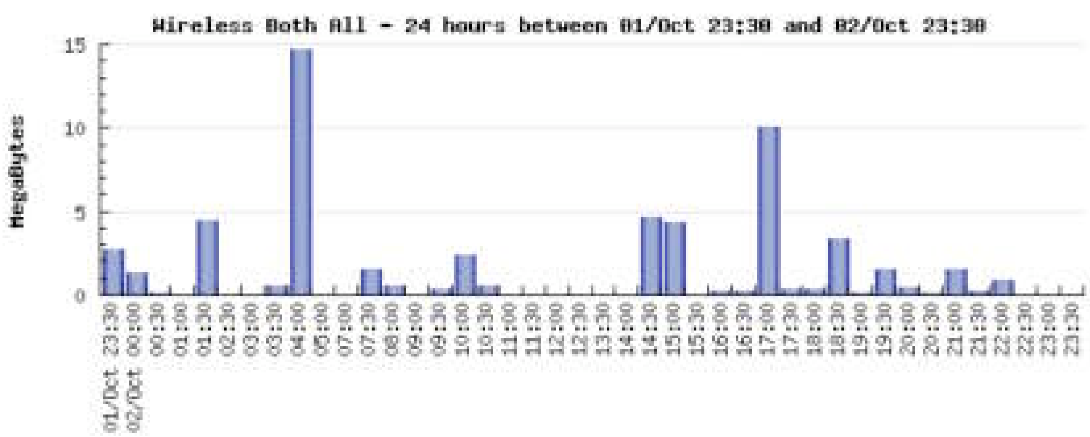


Fig D-2.12 WiFi node reaction
Location: Albany Theatre

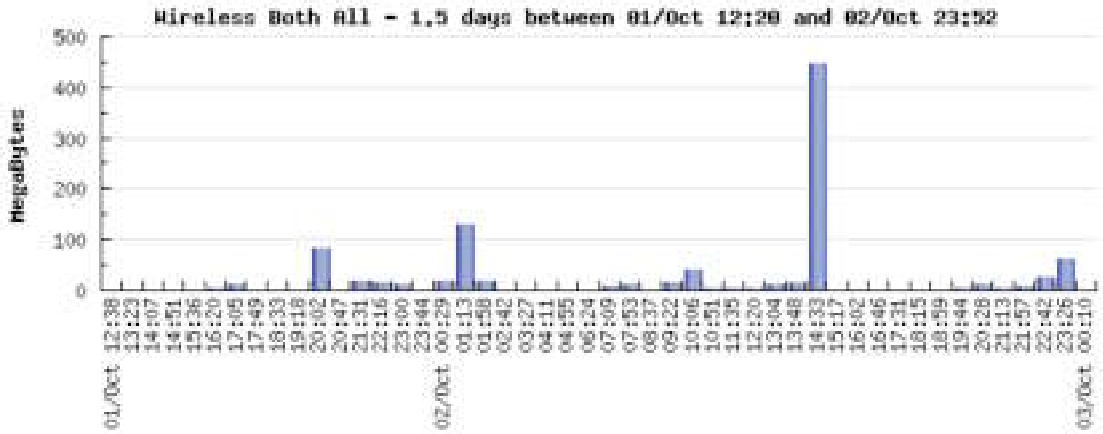


Fig D-2.13 WiFi node reward
Location: private residence, Deptford High Street, SE8 4AF

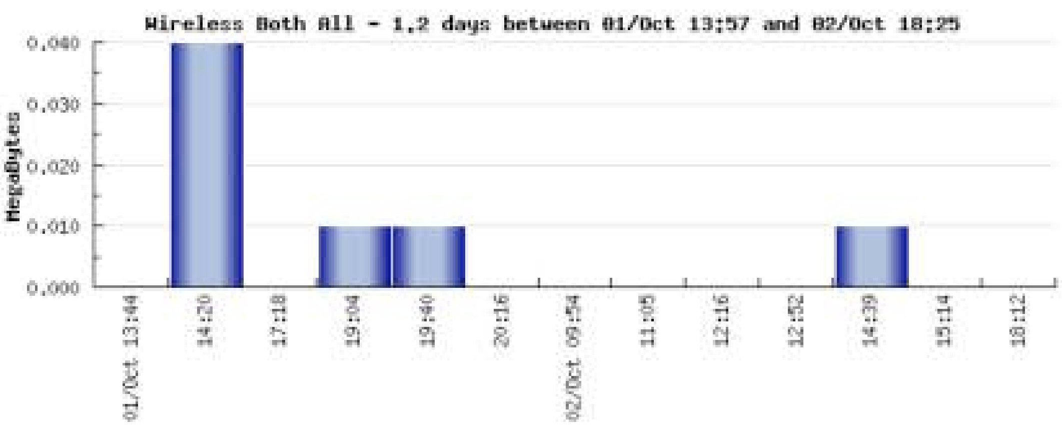


Fig D-2.14 WiFi node strategy
Location: Faircharm Trading Estate, 8-12 Creekside

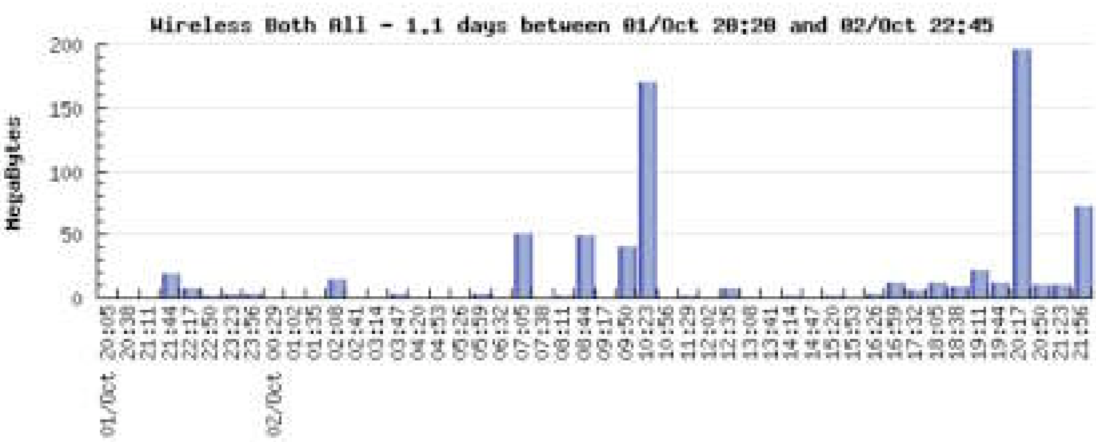


Fig D-2.15 WiFi node treasure
Location: Birdsnest Public House, Deptford Church Street

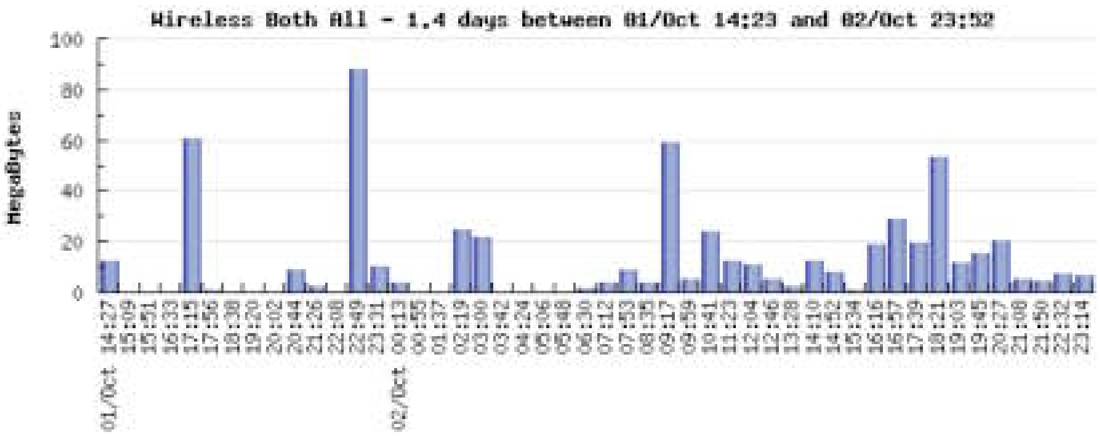


Fig D-2.16 WiFi node ubiquity
Location: private residence, 86a Deptford High Street

Appendix D-3

Empirical Study Two: WiFi usage by data volume amusement

00:11:f5:bc:29:9c	23 mb
00:0f:66:71:b5:8b	23 mb
00:19:db:04:43:4f	1 mb
00:0e:2e:a9:ba:62	1 mb
00:19:7e:a8:06:7b	1 mb

Beauty

00:16:cf:8e:1c:cc	1.2 gb
00:14:51:84:a2:ce	601 mb
00:1c:b3:b4:7f:5d	238 mb
00:13:02:bb:d2:a8	208 mb
00:11:24:26:f4:c0	130 mb

Belief

00:19:7d:39:67:f3	789 mb
cds227.lon.llnw.net.	53 mb
89.202.193.167	33 mb
cds258.lon.llnw.net.	32 mb
ool-182cdbc6.dyn.optonline.net.	32 mb

Cows:

00:1b:63:05:0d:09	1004 mb
00:16:6f:8b:cd:db	695 mb
00:16:e3:d3:f3:fe	284 mb
00:19:7d:6f:32:eb	167 mb
00:12:bf:1a:6d:a5	161 mb

Confidence

00:19:d2:45:25:4f	20 mb
80.69.12.47	2 mb
gayxxxparty.streamflex.com.	1 mb
akamai-cluster.enta.net.	885 kb
66.151.149.78	842 kb

Continuity

00:90:4b:93:04:0b	157 mb
66.55.151.83	26 mb
84.90.90.179	25 mb
server3.profilepic.com.	18 mb
18913102107.user.veloxzone.com.br.	18 mb

Emotion

00:12:f0:a7:67:68	600 mb
85.17.190.4	109 mb
cds258.lon.llnw.net	93 mb
84.53.134.199	64 mb
cds439.lon.llnw.net	63 mb
cds237.lon.llnw.net.	47 mb

Game

00:30:65:09:96:04	66 mb

00:30:65:07:a0:b8	31 mb
00:17:3f:74:c5:37	21 mb
00:16:cb:06:2f:b5	18 mb
00:17:3f:c5:fe:4d	4 mb

Greed:

00:1b:63:0a:5f:5c	22 mb
00:13:ce:f0:d0:9e	6 mb
00:13:ce:54:9e:5f	1 mb
00:19:db:08:f7:05	864 kb
00:90:4b:96:e9:64	573 kb

Invention

00:90:4b:b9:48:b9	301 mb
00:0b:7d:17:58:89	223 mb
00:13:02:7b:23:03	196 mb
00:0e:2e:a9:ba:62	139 mb
00:12:f0:9c:0f:ad	125 mb

Mudlarks

00:11:24:27:e9:98	482 mb
84-45-113-140.c4l.co.uk.	65 mb
224.Red-81-34-134.dynamicIP.rima-tde.net.	31 mb
static-108-70-7-89.ipcom.comunitel.net.	30 mb
29-2-18-190.fibertel.com.ar.	29 mb

Reaction

00:0c:f6:25:df:12	20 mb
00:13:ce:6d:10:33	15 mb
00:19:e3:02:dc:b9	9 mb
00:16:e3:d3:f3:fe	7 mb
00:16:6f:87:f4:dd	3 mb

Reward

00:19:7d:0d:f7:25	721 mb
211.103.153.75	57 mb
221.195.78.58	52 mb
58.211.0.220	46 mb
CPE001839e20e08-CM0014f859dfb2.cpe.net.cable.roger	33 mb

Strategy

00:19:e3:08:46:1f	58 kb
192.168.159.1	15 kb
192.168.159.210	7 kb
l1.login.vip.ukl.yahoo.com.	6 kb
84.53.134.208	5 kb

Treasure

00:0e:2e:39:19:70	340 mb
87.79.33.12	70 mb
63.210.156.201	57 mb

8.2.32.86	22 mb
x037056.its-s.tudelft.nl.	21 mb

Ubiquity

00:18:de:aa:fe:fe	186 mb
b2.c1.1343.static.theplanet.com.	56 mb
ip-72-55-140-12.static.privatedns.com.	37 mb
80.67.87.169	27 mb
195.8.214.6	16 mb

Appendix E

Curriculum Vitae

Curriculum Vitae

PERSONAL DETAILS
Name: Katharine S Willis
Date of Birth: 30.09.1972
Nationality: British

RESEARCH EXPERIENCE
October 2008 - current
Researcher, Locating Media Graduate School, University of Siegen

April 2006-April 2008
EU Marie Curie Research Fellow and Doctoral Candidate (Department of Media), MEDIACITY Project, Bauhaus University of Weimar

February 2005-April 2006
DAAD Doctoral Scholarship/Doctoral Candidate, Spatial Cognition Program, University of Bremen

September 2003-January 2005
Interactive Site-Specific Artist, London, UK

September 2001-August 2003
Masters in Architecture
Bartlett School of Architecture, University College London, London, UK

September 1996-July 1998
Diploma in Architecture
Bartlett School of Architecture, University College London, London, UK

September 1990-July 1993
Bachelor in Architecture
School of Architecture, University of Manchester, UK

PUBLICATIONS

Edited Volumes

Willis, K., Struppek, M., Roussos, G., Chorianopoulos, K. (2009 in preparation). Shared Encounters. CSCW series, Springer.

Book Chapters

Willis, K, Geelhaar, J. (2008). Information Places: Interfaces Between Physical and Digital Space in Foth, M (Ed). Urban Informatics. ICS Global.
Willis, K (2008). Spaces, Settings and Connections in Aurigi, A., De Cindio, F. (Eds) Augmented Urban Spaces: Articulating the Physical and Electronic City. UK: Ashgate Press.
Willis, K., Hoelscher, C., Wilbertz, G. (2007 accepted for publication). Understanding Mobile Spatial Interaction in Urban Environments. In Minker, W., Weber, M., Kameas, A., Hagras, H., Callaghan, V. (Eds). Augmented Intelligent Environments, Springer, UK
Willis, K. (2007). Situated Interactions: Spatial Setting and Mobile and Wireless technologies. Encyclopaedia of Mobile and Wireless Communications. Taylor and Page, US
Struppek, M., Willis, K. (2007 in press). Botfighter: A Game that Surrounds You, in Space Time Play, Birkhaeuser, Basel
Willis, K. (2007) Sensing Place: mobile and wireless technologies and urban space in Frers, L., Meier, L (Eds). Encountering Urban Places - Visual and Material Performances in the City, Ashgate Publishing, UK

Journal Articles

Willis, K., Hoelscher, C., Wilbertz, G. , Li, C. (2008 accepted for publication). Spatial Knowledge Acquisition with Mobile Spatial Information: Implications for Navigation Applications. Special Issue of Computers, Environment and Urban Systems, Elsevier Press
Willis, K. (2008 accepted). Hidden Treasure: Local Spatial Information. Aether; Journal of Media Geography.

Published Conference Papers

Willis, K., Hoelscher, C., Wilbertz, G. (2007). Understanding Mobile Spatial Interaction in Urban Environments. In Proceedings of 3rd IET International Conference on Intelligent Environments (IE07) (pp 61-68).
Li, C. and Willis, K. 2006. Modeling context aware interaction for wayfinding using mobile devices. In Proceedings of the 8th Conference on Human-Computer interaction with Mobile Devices and Services (Helsinki, Finland, September 12 - 15, 2006). MobileHCI '06, vol. 159. ACM Press, New York, NY, 97-100.
Willis, K. (2006-online). Changing Interactions and Infrastructures in Urban Public Space as Afforded by Mobile and Wireless Technologies, IAPS 2006, Egypt
Willis, K. (2005). The Potential of GPS Technologies to inform an Approach to Understanding Visual Sequences for the Observer in Motion, Generative Art Conference, Milan, Italy, December 2004

Workshop Papers

Willis, K, Hoelscher, C, Li, C (2007). Differences in Spatial Knowledge for maps and mobile maps. Proc. of Cognitively Adequate navigation Systems Workshop, KogWis 07, Saarbrucken
Willis, K., Chorianopoulos, K., Struppek, M., Roussos, G (2007). Shared Encounters. In Proceedings of CHI2007, April 28 – May 3, 2007, San Jose, USA.
Willis, K. (2006). Identity in Spatial Settings as Mediated by Mobile and Wireless Technologies, EASST Conference, Lausanne, 2006
Chorianopoulos, K., Willis, K, Colini, L., Teran, M., (2006). Dousing for Dummies: methods for raising public awareness of invisible communication networks. In Adjunct Proceedings of British HCI conference 2006.
Willis, K. (2005). Situated Cognition in the Use of Mobile Devices for Wayfinding Tasks, Mobile Maps 05 Workshop at MobileHCI05, Salzburg on 19th September 2000
Willis, K. (2005). Mind the Gap: Mobile Applications and Wayfinding, User Experience Design for Pervasive Computing, Pervasive 2005, Munich on 10th May 2005
Willis, K. (2005). Space/Place: urban public space and new media technologies. Urban Spaces and Private Quarters Panel at Conference for Technological and Aesthetical Transformations of Society, TU Darmstadt on 12th-14th October 2005

Poster Proceedings

Giles, T., Marienek, M., Willis, K., Geelhaar, J. (2007). Hide and Seek. in Poster Proceedings of Fifteenth ACM International Conference on Multimedia, (ACM MM 07), September 2007, Augsburg, Germany.
Li, C., Willis, K. (2006). Dynamic Aspects of Interaction in Wayfinding Tasks. in Poster Proceedings, Spatial Cognition Conference 2006, Bremen, Germany.

SELECTED LECTURES AND TEACHING

2007 - current: Supervision of Masters Thesises (University of Weimar, HdK Bremen, Lincoln University)
Summer Semester 2007: Taught Course: 'Information Places', Department of Media,
Spring Semester 2007: Taught Course: 'Space and Place', Masters Students,
27 October 2007: Invited Presentation and panel participation, ‚Access' Symposium, Shift Festival, Graz
20 June 2007: Presentation of Current Work, Department of Computer Science, Lancaster University
17 February 2007: Lecture, UdK, Berlin, Germany
13 December 2006: Lecture, "Situated Interactions", University of Weimar, Germany
12 Mai 2005, Lecture: "Space/Place", University of Manchester, Manchester, UK
November - July 2004: In-School Artist, "Download" Research Project, Whitechapel Art Gallery, London, UK
10 December 2002: Lecture, "Responsive Environments", Manchester School of Architecture, Manchester, UK

ACADEMIC QUALIFICATIONS

2008 Doctoral Thesis (pending), Department of Media, Bauhaus University of Weimar
2003, Masters in Architecture (commendation), Bartlett School of Architecture, U.C.L., University of London
1998, Diploma in Architecture (commendation), Bartlett School of Architecture, U.C.L., University of London
1993, BA(Hons) Architecture, University of Manchester, Manchester, UK

LANGUAGES

German (spoken semi-fluent), French (good), Spanish (good), mandarin Chinese (basic)

INTERESTS

Windsurfing, scuba diving, reading, travel

Appendix F

Declaration /Ehrenwörtliche Erklärung

Ehrenwörtliche Erklärung

Ich erkläre hiermit ehrenwörtlich, dass ich die vorliegende Arbeit ohne unzulässige Hilfe Dritter und ohne Benutzung anderer als der angegebenen Hilfsmittel angefertigt habe. Die aus anderen Quellen direkt oder indirekt übernommenen Daten und Konzepte sind unter Angabe der Quelle gekennzeichnet.
Bei der Auswahl und Auswertung folgenden Materials haben mir die nachstehend aufgeführten Personen in der jeweils beschriebenen Weise entgeltlich/unentgeltlich geholfen:
1. ....
2. ....
3. ....
Weitere Personen waren an der inhaltlich-materiellen Erstellung der vorliegenden Arbeit nicht beteiligt. Insbesondere habe ich hierfür nicht die entgeltliche Hilfe von Vermittlung- bzw. Beratungsdiensten (Promotionsberater oder anderer Personen) in Anspruch genommen. Niemand hat von mir unmittelbar oder mittelbar geldwerte Leistungen für Arbeiten erhalten, die im Zusammenhang mit dem Inhalt der vorgelegten Dissertation stehen.

Die Arbeit wurde bisher weder im In- noch im Ausland in gleicher oder ähnlicher Form einer anderen Prüfungsbehörde vorgelegt.
Ich versichere, dass ich nach bestem Wissen die reine Wahrheit gesagt und nichts verschwiegen habe.

Ort, Datum
Unterschrift