The Effects of Using GPS Systems on Spatial Knowledge Acquisition and the Respective Role of Spatial Design

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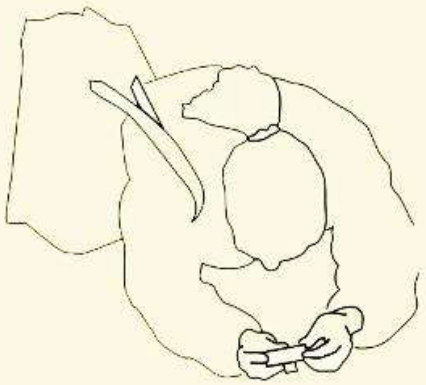
Thesis Abstract

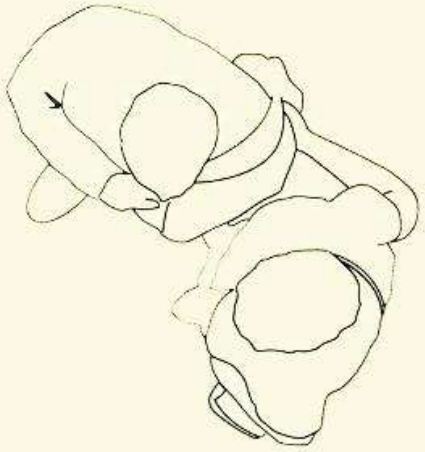
Navigation is one of the very first and common spatial behaviours that human-beings do within the physical environment; it is defined as a process of moving within the place with a goal of reaching a destination in a timely manner. This behaviour might seem to be a simple task since it is very common; however, it involves many multilevel cognitive processing and thus has received considerable attention from different disciplines. The recent emergence of Location-Based Services and the use of its popular form as mobile navigation systems by people in their everyday life have had a significant impact on navigation process. As people are increasingly using mobile navigation systems, research from a broad range of disciplines has examined the effectiveness of these systems, some of which have picked up worrying signs related to their use. One of these issues is concerned with spatial knowledge acquisition. The empirical studies, using different methods, have examined the effects of information provision by mobile navigation systems on people's spatial knowledge acquisition; they have studied the extent of which, people who use mobile navigation systems, can comprehend the physical environment comparing to those who do not use such systems or use other types of assistance, such as physical maps; or how accurately they can remember the location of the physical elements such as landmarks and spatial organisation between them, as well as how well they can estimate distances and directions between places. These studies have often demonstrated that mobile navigation systems are not very effective tools in helping people to acquire spatial knowledge. Nonetheless, there is a lack of study on the relationship between the physical features of the physical environment and the extent of spatial knowledge acquisition by mobile navigation systems. Research has shown that the physical environment, which navigation takes place within, is known as a key determinant in helping people to acquire spatial knowledge and has found many spatial factors of the physical environment that are influential on people's spatial knowledge acquisition, such as specific positions of landmark along the route, the form and length of routes, the shape and form of landmarks, the configurational complexity of the environment, the number of turns along a route, and the number of intersections linked together in a given setting. However, analysing the influence of such spatial factors on spatial knowledge acquisition of people using mobile navigation system has received little attention.

This thesis has two objectives, firstly to compare the spatial knowledge acquisition of pedestrians who used GPS for navigation in an unfamiliar urban environment in comparison to those who navigate the same environment without assistance, non-GPS group; and

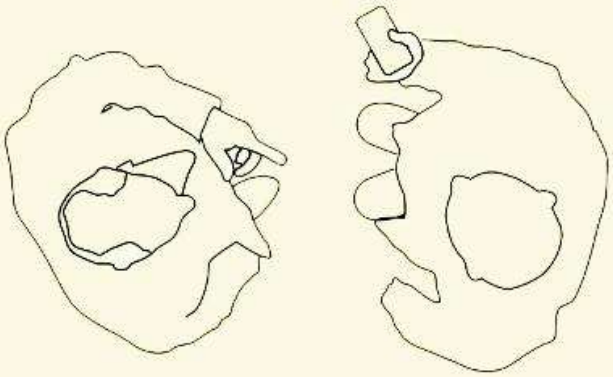
secondly, to identify the spatial factors that are influential on their spatial knowledge acquisition. To this end, this thesis firstly discusses the research background on studying the effects of using mobile maps on people's spatial knowledge acquisition as well as the intersection of spatial factors and spatial knowledge acquisition in navigation. The thesis then compares spatial knowledge acquisition among GPS and non-GPS groups, that have been through the study site, by using the method of sketch map drawing. Furthermore, the thesis examines the association between the extent to which the elements of the physical environment, specifically, landmarks, paths, and nodes are depicted correctly in the sketch maps amongst the two groups and their physical- spatial features in real world. The degree of depiction correctness of each element in the sketch maps are then examined for paths in relation to the path length and the number of turns along them in the real world as well as the existence of internal/external landmarks long the path; for nodes, they were tested in relation to the number of the node-legs, and existence of landmarks at their corners; for landmarks, their visibility to the participant in the site was tested. Also, a photo recognition test was used as a method to assess the two groups' (GPS, and non-GPS) visual knowledge of the site. A correlational study was then conducted to determine the relationship between the visual knowledge of the participants and the physical features of the elements in the site.

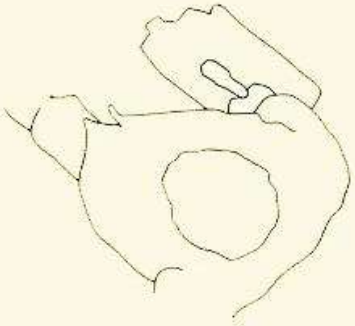
This study is grounded in the conceptual framework of Environment and Behaviour (E & B). Studying urban environments and their impact on residents' spatial cognition is a subarea of E & B studies, which aims to contribute to people's quality of life and well-being. It also can shed light on the spatial decision-making and behaviour of individuals. In practice, the applicability of cognitive studies can inform the future urban design and planning for a better living and working environment.

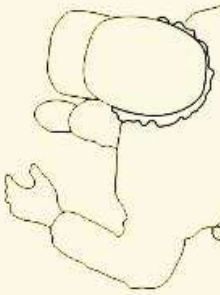


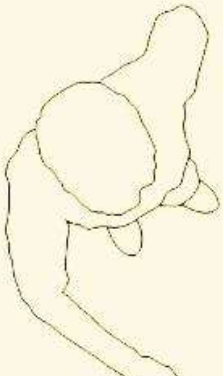


1. Introduction









Navigation is one of the very first and common spatial behaviours that human-beings do within the physical environment; it is defined as a process of moving within the place with a goal of reaching a destination in a timely manner (Arthur and Passini, 1992, De Jesus, 1994, Downs and Stea, 1973, Kaplan, 1973). This behaviour might seem to be a simple task since it is very common; however, it involves multi-level cognitive processing and thus has received considerable attention from different disciplines (Allen, 1999b, Klippel et al., 2005, Montello, 2005, Timpf, 2002, Winter, 2003). The recent emergence of Location-Based Services and the use of its popular form as mobile navigation systems (Evans et al., 1984b, De Jonge, 1962) by people in their everyday life have had a significant impact on navigation process. As people are increasingly using mobile navigation systems (Kitchin and Dodge, 2007, Laurier and Brown, 2008, Axon et al., 2012, Speake, 2015), a number of studies in a broad range of disciplines have examined the effectiveness of these systems, some of which have highlighted worrying signs about the use of these systems that are briefly discussed here.

1.1. Using Mobile Navigation Systems and Related Issues

First, from a neuroscience perspective, a small but increasing number of neuroscientists are now looking at the effects of navigation systems on the brain. Research (Bonnevie et al., 2013) has discovered different types of neurons in the brain that map the place and allow people to navigate in it, this discovery won the Nobel Prize in Medicine. These neurons create an inner positioning system, or in other words, 'brain's GPS' that let the brain know where we are in the environment and can navigate us from one place to another. However, researchers are now concerned about the changes in the brain due to a delegation of the navigational tasks from the 'brain's GPS' to 'GPS devices'; they believe that the little navigational efforts people do because of using the navigation systems can change the shape of the brain. Research suggests that the constant use of navigation systems could even result in atrophy of the neurons in the brain, which are involved with memory and navigation, in normal ageing and increases the risk of cognitive problems such as Alzheimer's disease (Neyfakh and So, 2013). As Eleanor Maguire indicated, the brain is plastic and its structure is correlated with the demands placed on it by a person. So, the potential negative impact of the navigation systems on the brain happens because people using such systems release their brain from the efforts of navigational tasks (memorising the landmarks, forming the cognitive map and etc.). Also, the brain has two different strategies for navigation, one relies on spatial knowledge (making a cognitive map based on the landmarks) and the second one is a

‘response strategy’ which is perfectly related to the way that GPS users navigate. The response strategy is easier, as Bohot says people go on “auto-pilot mode” (Neyfakh and So, 2013, P:2) and receive the right answers for moving within the place to achieve their destinations, however, it leaves people with little information from the place. It is interesting that video games are functioning similar to GPS systems and are also heavily using response strategies to take the players through their virtual places. In a recent research study has been shown that people playing more than 18 hours a week video game navigated differently from those who do not play (Janzen et al., 2001, Oman et al., 2000). Moreover, in another study, the researchers compared the brain’s function changes between participant navigated the study area by relying on memory to those who used response strategy (similar to GPS use). The study area was the Soho neighbourhood in central London. Scanning the brains of the participants using fMRI, they saw more activities in the hippocampus (which is a region of the brain including the neurons in charge of navigational tasks) of the participants who used their memories to make decisions at the intersections of the streets compared to those who were directed where to turn at the decision points (Jiang, 2006). It is evident that the use of GPS systems is changing the brain’s organisation, the way it works, and its navigational skills. Amir Homayoun Javadi states that using such devices "can be a shift in skills” and for today’s children who are growing up with these devices since they born, “their whole brain and its abilities in navigation can develop differently" (Lindberg, 1984. P: 9)

Second, from an architecture and urban design perspective, there has been a growing fear of the pervasive use of mobile phones and mobile navigation systems in public places. This popular quote from ‘The eyes of the skin’ says “Architecture is the art of reconciliation between ourselves and the world, and this mediation takes place through the senses” (Pallasmaa, 2012), but it is increasingly questionable that by the use of digital technology, which is called “the extension of man” (McLuhan, 1994) along with senses or even prior to senses in today’s world, if the architectural places could be understood and perceived in the same way that they used to be understood when the use of digital technologies was not expanded as we see today. Also, New Yorker architecture critic Paul Goldberger believes that using these devices in public places releases people from physical place and locks them in an ‘individualistic bubble’ and make public spaces less public (Jones, 1972). It has been observed that engagement with a phone screen is an inevitable part of people’s movements in the public places (Heft, 1979) and this constant use of mobile phones and GPS-based applications for navigation could turn people into “phone zombies” (Farman, 2013) who are

inattentive to their surroundings. This could result in decreasing the importance of physical places for people and lead to the "dissolution of the place" Baker (2004:2). Legibility of the physical environment has been always considered as one of the quality factors of the physical environment, which can ease people navigation. However, GPS devices often take people successfully to their destinations, regardless of the fact that the environment is legible or not. This is increasing the questions over the importance of physical legibility in the era of GPS and location-based systems.

Third, this issue, which is the focus of this thesis, is related to spatial knowledge acquisition of people who use mobile navigation systems for navigation. The empirical studies, using different methods, have examined the effects of information provision by mobile navigation systems on people's spatial knowledge acquisition from different perspectives: for example, they have studied the extent to which people who use mobile navigation systems can comprehend the physical environment comparing to those who do not use such systems or use other types of assistance, such as physical maps, also they have investigated how accurately they can remember the location of the physical elements such as landmarks and spatial organisation between them, as well as how well they can estimate distances and directions between places (Münzer et al., 2006, Aslan et al., 2006, Ishikawa et al., 2008, Krüger et al., 2004, Willis et al., 2009). These studies have often demonstrated that mobile navigation systems are not very effective tools in helping people to acquire spatial knowledge.

1.2. State of the problem: Spatial knowledge acquisition and physical environment

The key element of all aforementioned studies on spatial knowledge acquisition is their attempts to examine the effects of different types of mobile navigation systems with different types of information modalities (e.g. audio, text, map, etc.) on the user's spatial knowledge acquisition. These studies are supported by using many empirical tests and observations in different physical settings. Nonetheless, there is a lack of study on the relationship between the physical features of the different properties of the physical environment and the extent of spatial knowledge acquisition by mobile navigation systems. Research has shown that the physical environment, which navigation takes place within, is known as a key determinant in forming people's spatial knowledge and has found many physical-spatial features of the physical environment that are influential on people's spatial knowledge acquisition, such as specific positions of landmark along the route, the form and length of routes, the shape and

form of landmarks, the configurational complexity of the environment, the number of turns along a route, and the number of intersections linked together in a given setting. However, analysing the influence of such spatial factors on spatial knowledge acquisition of people using mobile navigation system has received little attention.

In using GPS systems in navigation, there is an interactive transaction between three main contributors, namely, individuals, GPS systems and the physical environment. However, investigating the relation of the physical environment to this transaction has been often overlooked. According to the study by Li (2006), which is one of the few studies that has looked at the relationship between the use of GPS systems and the physical environment, she emphasises that the spatial layout of the physical environment and wayfinding difficulties people encounter in a physical setting affect the way and amount of their use of information provided by GPS systems. As part of the study, she demonstrated the amount of GPS system use in relation to the spatial layout of her study area. These analyses showed GPS use increased at the decision points, and the destinations where the next task needed to be planned, however, the participant's GPS use along the route was minimal.

In this thesis, given the fact that physical environment is an important determinant in forming people's spatial knowledge, the effects of the physical environment and its physical-spatial features on the spatial knowledge acquisition of people using GPS for navigation are studied.

1.3. Aims and Objectives

With the knowledge, that information provided by mobile navigation systems are in different formats (texts, audio services, maps, and pictures, etc.) and different types of information can affect differently on the acquisition of spatial knowledge and the success of way finding (Li, 2006). This thesis focuses on using the 'mobile maps' format such as Google maps, which are widely being used in pedestrian navigation (Kalin and Frith, 2016). The thesis then has two objectives, firstly to compare the spatial knowledge acquisition of pedestrians who used Mobile Maps (MM) for navigation in an unfamiliar urban environment in comparison to those who navigated the same environment without assistance, the Direct Experience group (DE); and secondly, to identify the spatial factors that are influential on their spatial knowledge acquisition. To this end, the research will firstly discuss the background on studying the effects of using mobile maps on people's spatial knowledge acquisition as well as the intersection of spatial factors and spatial knowledge acquisition in navigation. The

thesis then compares spatial knowledge acquisition among MM and DE groups that have been through the study site, using sketch map drawing as one method. Furthermore, the research will assess whether there is any association between the extent of which the elements of the physical environment, specifically, landmarks, paths, and nodes are depicted correctly in the sketch maps among the two groups and their physical-spatial features in the real world. The degree of depiction correctness of each element in the sketch maps are then examined for paths in relation to the path length and the number of turns along them in the real world as well as the existence of internal/external landmarks along the path; for nodes, they were tested in relation to the number of the node-legs, and existence of landmarks at their corners; for landmarks, size, shape, signage, maintenance quality, texture, style, contour, colour/texture, visibility from roads, symbolic significance, use intensity, naturalness, siting characteristics, uniqueness of function, and type of nearby road were tested.

1.4. The significance of the Study

This study is grounded in the conceptual framework of Environment and Behaviour (E&B). Studying urban environments and their impact on peoples' spatial cognition is a sub-area of E&B studies, which aims to contribute to people's quality of life and well-being (Lynch, 1984). It also can shed light on the spatial decision-making and behaviour of individuals (Livingstone et al., 1994). In practice, the applicability of cognitive studies can also inform the future urban design and planning for a better living and working environment (Nasar, 1994).

The significance of this study includes two aspects. First, from a theoretical aspect, it provides additional empirical evidence to support the argument that the urban environment and its physical-spatial features are a primary root for human beings to shape their cognitive maps.

1.5. Thesis outline

This thesis consists of eight chapters, which are presented within three parts. Part 1 (Chapters 1, 2, and 3) provides the research background for this thesis. Following the Introduction (Chapter 1), which presented the significance, the aims and objectives of the study, chapters 2 and 3 focus on the literature of relevant theoretical positions and research frameworks about human spatial cognition. Chapter 2 specifically aims to review and discuss the theoretical underpinnings of spatial knowledge acquisition in a physical environment, in general, and the

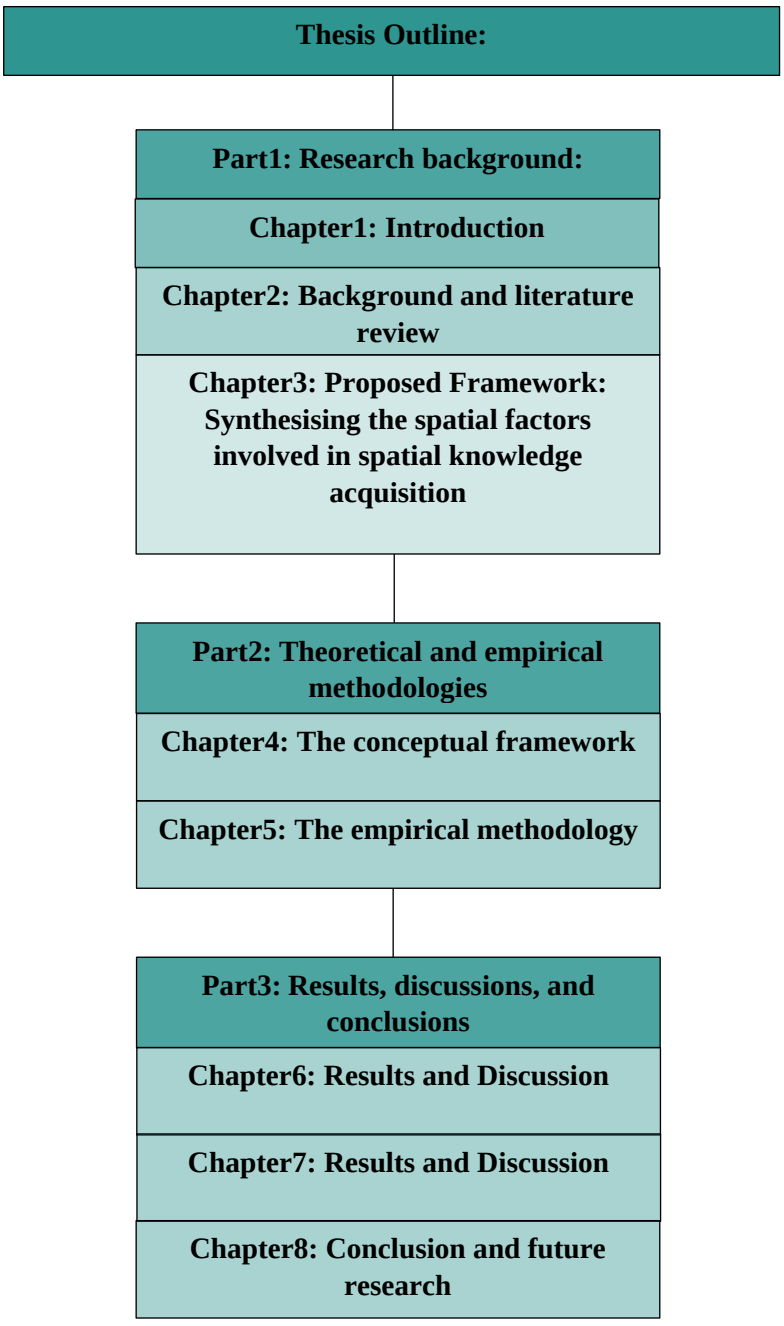
effects of using GPS systems on peoples' spatial knowledge acquisition, in particular. To this end, it explains the theories concerning the acquisition and development of spatial knowledge as well as discussing all the factors that affect spatial knowledge acquisition, specifically, navigation tools. It then goes through the effects of mobile maps, as navigation tool, on spatial knowledge acquisition and discusses the results of relevant research. It also debates the contribution of physical environment as a factor to people's spatial knowledge acquisition. As this thesis aims to look at the effects of physical environment on spatial knowledge acquisition, Chapter 3, after reviewing the literature related to the effects of the physical environment on spatial knowledge acquisition, introduces a framework, which incorporates all the physical-spatial factors that affect people's spatial knowledge acquisition. This proposed framework can be also used by urban planners and designers for evaluating the physical environment in relation to the extent to which people can acquire spatial knowledge, or in other words, how well they can comprehend the environment. This framework is further used for analysis of this study; the association of a series of factors presented in this framework with the extent to which mobile map users acquired spatial knowledge are studied.

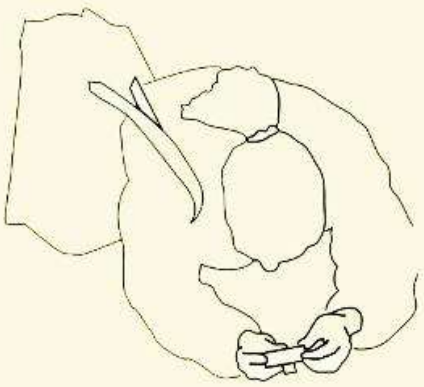
Part Two presents the theoretical and empirical methodologies for the study (Chapters 4 and 5). In Chapter 4, the conceptual framework of the study is presented. This chapter deliberates how according to the aims of the thesis, the effects of the physical environment and its physical spatial factors on the spatial knowledge acquisition of people who use GPS for navigation will also be examined. This provides a theoretical basis for the empirical study of the thesis. Chapter 5 presents the empirical methodology that was undertaken in the research. Along with the experimental approach, this chapter discusses the data collection and analysis methods used in this research.

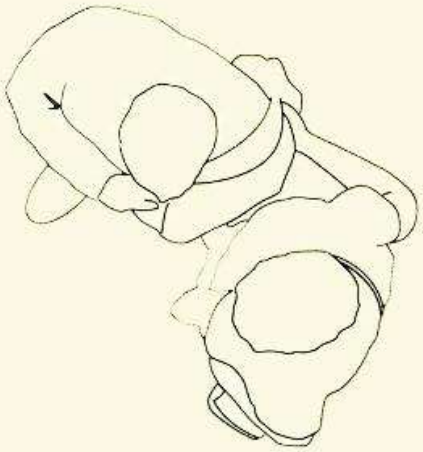
Part Three consists of the results, discussions, and conclusions and includes three chapters (Chapters 6, 7, and 8). Chapter 6 reveals the key results of the sketch map analysis, which were used to examine the effects of the elemental factors of physical environment, namely, paths, nodes, and landmarks on the spatial knowledge acquisition of people who used GPS for navigation. In doing so, the effects of physical-spatial features of these elements on spatial knowledge acquisition of GPS users are presented. For paths, the number of turns along the path, length of the paths, and existing internal and external landmark along the path were tested. For nodes, the number of paths entering the nodes (node-legs), and existing landmarks at the corners of the nodes were examined. And for landmarks, they were tested for their

visibility to the participants in the site. This chapter also contains the discussion on the presented results. In Chapter 7, the results of photo recognition test are explained. This method was used to find out the physical-spatial features that can contribute to the memorability of the buildings among GPS users. Also, this chapter contains the discussion on the results of the photo recognition test. The closing chapter, Chapter 8, contains the conclusions to the study and suggestions for future research. Figure 1.1 illustrates the thesis outline.

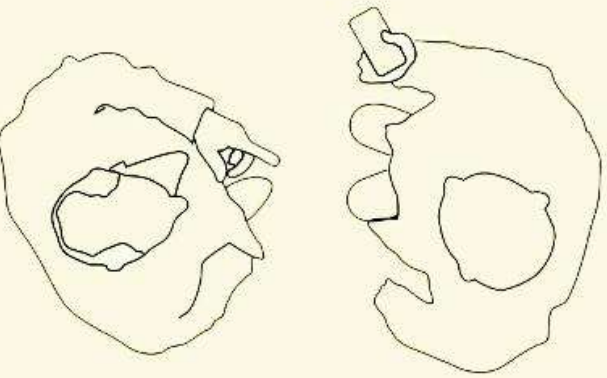
Figure 1.1. Thesis Outline

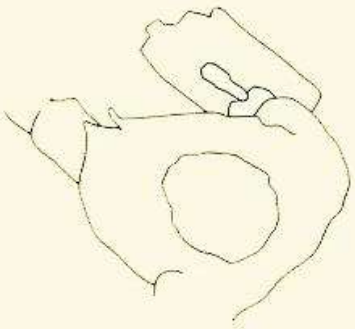


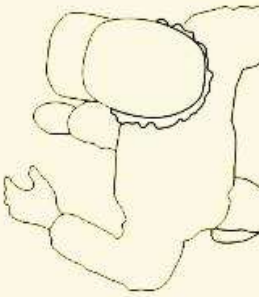


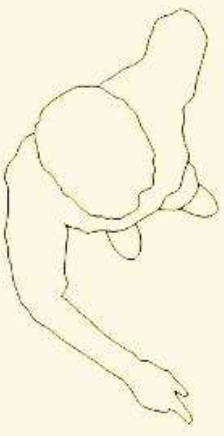


2-Background and literature review









2.1. Introduction:

This thesis aims to understand the effects of using mobile maps on people's spatial knowledge acquisition as well as the effects of the physical environment on spatial knowledge acquisition of people who use mobile maps for navigation. This chapter, therefore, provides a theoretical construct for the aims of the thesis. To this end; this chapter firstly discuss, in general terms, the syntax of technology in the design disciplines. Secondly, it provides the research background on spatial knowledge acquisition and discusses the theories of spatial knowledge development. thirdly, the chapter presents different means of spatial knowledge acquisition, including GPS-based navigators, during navigation. Forth, the chapter demonstrates different types of technologies that have been used to assist people's navigation. Fifth, the chapter goes on to discuss the role of the physical environment and its spatial factors on spatial knowledge acquisition. Finally, it elaborates on the findings of the previous studies which have investigated the effects of GPS-based navigators on people's spatial knowledge acquisition.

2.2- The syntax of technology in design

The current market demands urban designers and architectural designers to better utilise emerging digital technologies, which have come to create this alienating affect our spaces. Our objects, living spaces, and buildings, which manipulate, contain, and consume our environments, must also function as liaisons that connect us to our environments. Technology in the architecture of the cities should strive to promote a greater understanding of the world, of material and space, of personal and social experience, and the inherent scarcity of the natural fabric which fuels and protect our lives. Rather than serving as the material and physical separation of self and world, technology can serve a greater role as extensions rather than substitutions to how we mediate the world.

It is important, this distinction between technology as an extension, versus technology as a substitution. Even though technology often takes a role beyond what humans can naturally accomplish, particularly in the role of collecting minute information from the physical environment with uniform precision, filing it away, and processing this data through complicated and layered questioning that we devise, these capabilities however, should not in any way diminish the incalculable means by which humans process the physical, ephemeral environment, and social interaction. This thesis aims to reveal that new opportunities that technology can reveal impressive and nuanced correlations that better help us understand the

world beyond what our natural senses can directly absorb and process. But in many ways, our human senses and analytical skills are capable beyond any digital calculations, working in often mysteriously advanced ways while dramatically colouring our lives and enhancing our experiences. It should be said then, that the direction of this technological advancement in the architecture of cities should encourage and improve our evolved skills and intuitions, not hinder them or break their legacy.

For starters, it is important to acknowledge the arguments concerning technology that has already influenced architecture work and architectural thinking. Quite often the philosophical ideas regarding post-industrial "dwelling" and technology have been heavily rooted in philosophers such as Heidegger, Deleuze and Derrida. In the more current news, architects like Neil Leach and Mark Goulthorpe purport that a reverse process of investigation could develop new definitions of architecture. Instead of starting with a structure and infusing it with technical ability, designers who are fluid in the use and implementation of more advanced technologies are looking for new ways for information and sensorial technology to become architectural material. It is this data and research from which new architecture might be developed that this thesis will address and pursue. Innovators in this field include architects like Diller and Scofidio Renfro, Greg Lynn, and MVRDV, and others who have implemented and designed with heavy technological mechanics and philosophies and social research. These established firms have strong examples of built and unbuilt architectural work, which have gone through rigorously design processes rooted in hard data and research.

In order to properly address technology, it is important to refer to Heidegger two major texts "Building Dwelling Thinking" (Pérez-Gomez, 1997) and "The Question Concerning Technology." (Leach, 2002) These texts have greatly influenced architectural thinking. Heidegger describes architecture as that which is beyond building for necessity and shelter, that architecture, which allows for "dwelling" is a noble act. In fact, Heidegger writes that dwelling is that which makes us most authentically human and separate from other living things. Moreover, it is in this dwelling that humanity can be revealed. In contrast, Heidegger questions whether dwelling in the technological age is even possible, since technology, as an ordering and re-presentation of the material world, has the effect of cloaking the human spirit. But he does say, however, that if dwelling were to existing today, then it must be through technology since technology mediates all aspects of our lives. While Heidegger continues to be a substantial figure in architectural theory, however, some architectural theorists claim that Heidegger's argument cannot fully encompass people's relationship with modern technology

today. For Neil Leach, editor and contributing writer to Designing for a Digital World, humans have a much more dynamic and flexible attitude towards technology than Heidegger allowed for in his interpretation.

For Leach, the philosopher Derrida offers a different perspective. Derrida argues that the principle of hermeneutics is important, that any reading of symbolism should consider the agency of the interpreter. Furthermore, he questions whether the authenticity or inauthenticity of an object can endure once the memory of its creation is lost. Leach purports that people's familiarity and attachment to technology allows for poetic appropriation. He cites our tendency to name our cars and talk to our computers, as examples of how we have absorbed these objects and have begun to identify us with them. With the advent of mobile media, we are continuous socializing and plugged in — so that technology and identity appropriation is also increasing non-material and ephemeral. For Leach, Heidegger's interpretation of technology is static and rigid. instead, Leach argues that in fact the interpretations of architecture and technology are a dynamic condition, constantly changing, while we, as interpreters are constantly adapting. This is an important point for contemporary architectural theorists. Leach, however, is also aware of the aesthetization and anaesthetization of architecture; given the ability to build with tremendous complexity through a digital means does not mean that we should. Nonetheless, he contends that "well-designed technology" has the ability to overcome alienation.

It is important to note that architectural theorists have not dropped the fear of alienation since Heidegger and Derrida. In fact, many critics believe there is a great danger when technology allows for such extreme complexity in formation, calculation and construction. These digital design work have been criticized as being unrealistic, incomprehensible, and lacking translation to reality. But digitals would argue that these representations are rational, formal outcomes that are based on data-based inputs and that the designer is charged with choosing from enormous variations of outcomes. Author Sarah Chaplin writes that designers specifically then, have the larger task of designing the interface of technology that this is where people can connect with their world (Chaplin, 1995).

2.2. Spatial knowledge acquisition:

We as humans live in space and this tends to be a fact which does not require us to think about it, however, living in a space entails people to continuously interact with space and process the received information from the surroundings. People move around, perceive the environment around them, acquire knowledge about it, store it to their minds, modify the information collected, and used it when it is needed, either consciously or unconsciously. These ultimate process that happens in people's everyday lives are referred to *cognitive mapping by* (Downs and Stea, 1973). Examples of knowledge about space are name of places, distances and direction between the places, and the relational organisation between places. People use such spatial knowledge to get from home to work, to plan their travels between different places, to give navigational directions to others. This knowledge which is stored in the brain, determines the people's behaviour in the environment, in other words, people's behaviour is not merely based on the physical environment but on people's spatial knowledge or mental representation of the physical environment. This has been a major premise in behavioural geography, which emerged in 1960s (e.g. see G. GOLLEDGE et al., 2000). Since then, many researches from different disciplines studied the concept of mentally represented environments. The term *cognitive map* has been remained as a general term used to explain the cognitive process involved in the acquisition, representation, and processing of information about real physical environments, however, researchers in different disciplines have used different terms such as mental maps, mental image, and mental pictures, which have the same meaning as cognitive maps (Downs and Stea, 1973). The term 'cognitive map' is widely used in a number of disciplines such as environmental psychology, social psychology, anthropology, geography, cognitive studies, city planning, urban design, and architecture. Cognitive maps are incomplete, in segments, and distorted internal representation of the physical environment. They keep getting updated; so at one occasion, it is just a snapshot of the state of spatial knowledge and will get changed as time goes on. However, cognitive map, according to cognitive psychology, is not a "picture in the head." It is different from a picture as it is not detailed, it can be distorted, and it is segmented into meaningful pieces (Anderson, 1996).Moreover, a cognitive map is also a "compact orderly collection of knowledge. It contains more information than one can generally conceive at once, thus permitting one to anticipate, to react, to consider next possible events" (Kaplan and Kaplan, 1982, P: 63). Also, cognitive maps can help with decision making even if lots of information is missing. Furthermore, they are known to be essential contributors in the adaptive process of spatial decision-making; they are used to lead spatial behaviour, such as

wayfinding in the environment (Kitchin, 1994). Evans (1980) argued that cognitive maps represents spatial organisation between places, relative distances, orientation, and cardinal directions of different parts. (Stea, 1969) stated that cognitive maps also contain the information about the hierarchical arrangement of places in the environment with regards to size, and relative distance. He also added that they have the information about the degree of interconnectedness between places, and cognitive maps, although are not cartographic, experientially hold some map-like qualities. A good and accurate cognitive map facilitates the subject's movement and navigation within the actual environment.

Acquiring spatial knowledge from large-scale environments (e.g. urban environments), which is the focus of this study as well, has been investigated by various researchers. Ittelson (1973) deliberated the characteristics of large-scale environments and stated that perception of large-scale environments should be concerned differently from traditional object perception. Significantly, people cannot comprehend the spatial layout of large-scale environments in its entirety from one viewpoint; as a result, people should move within the environment and explore it, and integrate the spatial knowledge acquired from different viewpoints and movement experiences. Therefore, their spatial knowledge develop over time as they experience the environment more often. This spatial knowledge or cognitive maps become more accurate over time then (Golledge, 1999). Spatial knowledge development in a 'new' large-scale environment is called *spatial microgenesis*, whereas, the spatial knowledge development across life-span is referred to *ontogenesis* (Ishikawa and Montello, 2006).

2.3. Theories of spatial knowledge development

What characterises the most theories of spatial knowledge development are the '*stage'* progress and generic '*parallelism'* that happen between different kinds of development, *microgenesis* and *ontogenesis* are two kinds of it (White, 1983). These theories believe that there is a steady developmental progress toward an increased level of abstractness, flexibility, integration, and perfection. The stages of spatial knowledge development are hierarchically organised and each stage is qualitatively different from the other one. The later stages are formed upon and surround the earlier stages (Mandler, 1988). One of the fundamental theories for spatial knowledge development is Piaget's developmental theory. (Piaget and Inhelder (1987), Piaget and Inhelder, 1948) discussed the spatial knowledge development of children in terms of three stages of spatial relations, namely, topological, projective, and Euclidean. Regarding topological knowledge, it is concerned with qualitative relationships, such as, proximity, separation, order, enclosure, and continuity. Projective knowledge

contains the spatial relations tied to a specific viewpoint, and Euclidean knowledge compasses metric information, such as distances, and directions. Piaget and Inhelder argued that children, in their experiments, initially understood the environment topologically, and projective and Euclidean knowledge gained, in apparel, but in a stage later. However, it took longer that Euclidean knowledge gets to the state of equilibrium. Hart and Moore (1973) expanded on this theory and characterised the space in regards to three kinds of frame reference, namely, egocentric, fixed, and coordinated. They explained that the knowledge in children develop from an egocentric space into allocentric space, meaning, space which is concerned with a specific orientation into a space in which different scenes from different viewpoints are connected. Similar to Piaget and Inhelder, they worked mainly on ontogenesis knowledge development, but briefly took on microgenesis development.

Developing these arguments, Siegel and White (1975) suggested a framework to explain microgenesis development of spatial knowledge. This framework proposes that spatial knowledge development occurs in three stages of *landmark knowledge, route knowledge, and survey knowledge*. Landmark knowledge is referred to knowledge of discrete object, locations, scenes that are salient in the environment to the traveller. They say that "landmarks are unique pattern of perceptual events at a specific location, they are predominantly visual for human adults, they are the strategic foci to and from which one travels". Accordingly, landmarks cite a specific geographical location. As such, "the intersection of Broadway and 42nd Street is as much a landmark as prudential centre in Boston, the Eiffel tower in Paris, or the billboard advertising Winston cigarette" (23). They also added that conscious knowledge of where we are going to is landmark knowledge (e.g. we are going to the park, we are coming from the office). Also, landmarks do classify the beginnings and endings and also are employed as intermediate course-maintaining devices. Because this helps with having correct navigational direction in the environment (Gladwin, 1972).

Regarding route knowledge, this stage of knowledge contains sequences of landmarks and related navigational decision (e.g. go straight for two blocks and turn right at that landmark). Siegel and White (1975) stated that at the beginning of the journey, if one knows that s/he is going to see a particular landmark or sequence of landmarks, the one has a route. If the targeted landmarks did not happen, the question from the subject is what am I doing here? Am I on the correct way? Based on their research, "the space between landmarks is at first 'empty', and then gains 'scaling' with accumulative experiences" occurred over time in the environment (p:29).

According to this framework, landmarks and routes are known as "necessary and sufficient elements for minimal representations that allow wayfinding to occur" (p: 23). Routes can give shape to the knowledge representative of environment.

In order to have survey knowledge formed, landmarks and routes should be interconnected with each other, even those that are not directly connected. To summarise their theory, they put it up that people's development of spatial knowledge occur in three different stages: Landmark knowledge, to route knowledge, and to survey knowledge. This framework has been broadly influential in the research, (Montello, 1998). Montello (1998), and Ishikawa and Montello (2006) used the name the *dominant framework*. In this thesis as well, this framework is referred to the dominant framework.

The terms (landmark, route, and survey knowledge) have been used in to the dominant framework can be tracked back to the work done by shemyakin (1961). He identified the differences between route knowledge representation and survey knowledge representation through comparing the sketch map drawn by children from a familiar place. He pointed out that the route knowledge developed earlier than survey knowledge. He stated that the survey-map type of representation cannot be formed unless a certain amount of route-map type of representation is accumulated. He added that these two types of knowledge representation exist not only in children, but also in adults.

The dominant framework identifies three kinds of spatial knowledge, namely, landmark knowledge, route knowledge, and survey knowledge. This is a reminiscence of Lynch's theory which recognised five elements of physical environment (landmarks, nodes, routes, edges, and district) which are in correspondence with spatial knowledge. Having said this, the developmental stages of predominant framework have not received substantial empirical supports. Also, dominant framework drew an analogy with ontogenesis and explained that adults, in a new environment, do not acquire metric knowledge (knowledge of distance) in the early stages (i.e. landmark knowledge, and route knowledge), unless they explore the area over time and accumulate experiences with the environment. In contrast, other researchers have shown that people with minimal exposure to a new environment gain metric configurational knowledge can perform a navigational task (e.g. orientation, making decision at the decision points, taking shortcuts, going back directly to the start point, estimating the distances) at least better than chance. e.g. see (Klatzky et al., 1990, Landau et al., 1981, Landau et al., 1984, Leonard and Newman, 1967, Loomis et al., 1993, Rieser et al., 1980,

Sadalla and Montello, 1989, Worchel, 1951). These works, based on their empirical studies, argue that people can comprehend the distances and orientation accurately with minimum experience in a new environment, while the dominant framework consider it as impossible without accumulated experiences in the environment.

Moreover than being inconsistent with other research mentioned above, the dominant framework is very descriptive and does not provide the details of spatial knowledge developments in details. In a generic way, it only describe that the spatial knowledge progress from landmark knowledge, to route knowledge and then survey knowledge, however, it does not elaborate the fact that how much effort or time is needed for going from one stage to another. For instance, it says that landmarks are first learned and then a sequences of landmarks are learnt, but do not provide any details about the interval between the two states, or says that "landmarks and routes are interrelated as a function of repeated experiences" (Siegel and White ,1975, p:30), but it does not specify how much experience is needed (Blades, 1991) gave a criticism to the dominant framework because of descriptive and non-clear essence of it.

Acknowledging this gaps with in the dominant framework, Montello (1998) put forward a new framework to explain the spatial knowledge development. This framework opposes the unrealistic assumptions of the dominant framework that no metric knowledge being form at the early stages of spatial knowledge, and states that "metric configurational knowledge begins to acquire on first exposure to a novel environment" (Montello, 1998, p:146). In Montello's framework, there is a continuous (quantitative) development rather than discrete (qualitative) progress. A few other researchers made similar points, but as not as detailed as Montello did. (Evans, 1980) said that "the operational distinction between these Piagetian stages may reflect scalar differences instead of distinct stages of spatial cognition" (p.275). Hirtle and Hudson (1991) asserted that there are not discrete knowledge states, but rather there is a continuum between route and configurational knowledge (p.343). McDonald and Pellegrino (1993) said that " different type of spatial knowledge [landmark, route, survey knowledge] maybe required to different degrees,… they are not necessarily acquired in the developmental order, and…in natural setting, some types of spatial knowledge may not be acquired at all (p.54).

Studies have examined the spatial development of people in a new environment. Most of them used sketch map drawing as a method that externalises the spatial knowledge conceived

by people. This method became popular and was broadly used after Lynch's work, which used this method in his research (1960). For example see (Appleyard, 1970, Beck and Wood, 1976, Devlin, 1976, Humphreys, 1990, Moore, 1974, Murray and Spencer, 1979, Spencer and Weetman, 1981, Pearce, 1977, Pocock, 1976, Walmsley and Jenkins, 1992). These studies counted the number of elements (landmarks, routes, nodes) drawn on the sketch maps, or classified the sketch maps based on their style (e.g. spatial, sequential) or the degree of their complexity (e.g. chain, branch, scattered, mosaic, and pattern). Also, some of them tested the association between these characteristics of the sketch maps, and the characteristics of the individuals who drew these maps. Among these characteristics, one had received more attention was the degree of people's familiarity or experiences with the physical environment. In order to test the effect of familiarity on people's spatial knowledge, they examined the spatial knowledge of people with different length of residence, such as local residents, and short-term visitors. The studies did not show a consistency in results; in some studies, the most dominant element was landmark and spatial style for the style of the sketch maps, whereas, some in some other studies, the main dominant element was route and the style of the maps were sequential. These differences are discussed and referred to several reasons 1) differences in the degree complexity of the study area, 2) the difficulty in essence of classifying the sketch maps, 3) the lack of control over the experiments in terms of tools (e.g. maps, verbal description, and etc.). Some of the researchers (e.g. Murray, and Spencer) indicated that these differences in sketch map drawing could be results of individual abilities in drawing. Although some of these researchers elaborated the spatial knowledge development based on the sketch maps (e.g. Moor), their results did not show a conclusive conclusion.

Some interesting results were found in analysing the sketch maps; the number of elements depicted on the maps increased when familiarity increased. Beck and Wood (1976) and Devlin (1976) noticed that when familiarity raised, the basics of the sketch maps did not change very much, but included more details. This shows that people learn more landmarks and paths over time to fill in the sketch maps. However, these results did not show anything regarding the accuracy of the drawn sketch maps. Evans et al. (1981) studied the progress in accuracy of spatial knowledge in the same people for after two weeks, and 10 months then. They found that ordinal accuracy did not change between two times, but Euclidean accuracy improved. In this sense, Golledge (1978) put forward a conceptual framework, which is known as *anchor point theory*, which explain the spatial knowledge development based on a

'filling-in' process in sketch maps. He specified that people initially acquire spatial knowledge from the areas that they often use, such as, their home, work, the café they use most, and when amiliarity increased, they start gaining spatial knowledge about the surrounding area. Accordingly, people's spatial knowledge about the area is first skeletal including the fundamental nodes and paths, and as time goes on it become more detailed with spaces in between filled in with details.

A group of researchers focused on cross-sectional studies examining people's spatial knowledge in relation to their level of familiarity and experience with in the physical environment; they have tested spatial knowledge of people with different length of residency in a specific neighbourhood. Herman et al. (1979) compared the spatial knowledge of three different groups according to the length they have live on the university campus that they studied. The three groups were : a) three weeks, b) three months, and c) six months. They evaluated landmark knowledge, route knowledge, and survey knowledge of their participants by asking them a) to recall and match the buildings of the campus, b) to give direction between two pairs of buildings on campus, c) to rank order the distances of straight-lines between two pairs of buildings. For the first two tasks, the three months group performed better than three weeks group, however, three months and six month group did not differ. For the third task, they merely compared the three weeks and three months groups and noted that the latter had more detailed spatial knowledge than the former. They came to this conclusion that the participants acquired accurate landmark, route, and survey knowledge only after three weeks, and then their knowledge become more detailed in the next two months, but does not differ much after that. However, there are two things to be considered in interpreting the results of their study; first, the amount of experience for each group was not controlled (simply the length of residency in a neighbourhood cannot be equivalent to their amount of their experience there). Second, the way that those groups experienced the site was not controlled, some of them might experience the site solely on direct experience, and some might use maps (the tools used in navigation affect spatial knowledge acquisition, e.g. see (Thorndyke and Hayes-Roth, 1982, Ishikawa et al., 2008).

A few numbers of studies have experimentally tested the development of accuracy of spatial knowledge; one of which is the study by Gärling et al. (1981). They had participants that travelled a route either on foot or car, they were then required to do a series of tasks, naming landmark in the order they saw them, estimating the distances and direction between landmarks. They were asked to repeat the route travel and navigational tasks in three

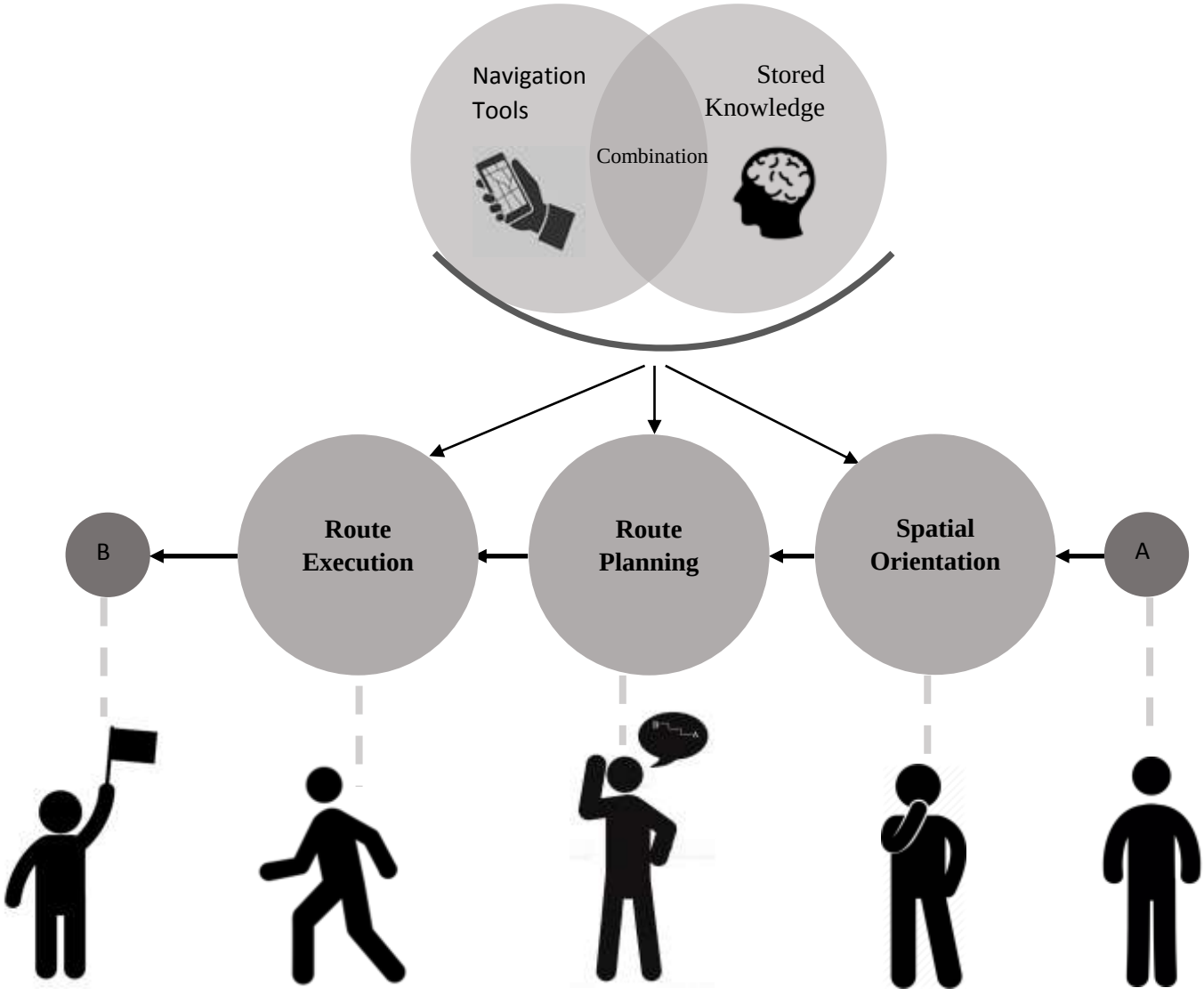
sessions. They came back for the second session in 6 to 8 days; it was found that, in the second session, participants ordered the landmarks almost perfectly comparing to the first session, also the accuracy in direction and distance estimation increased after the first session. Also, it was noted that the participants who travelled by car acquires spatial knowledge quite faster than participants who walked.

Also, Herman et al. (1987) tested the development of accuracy of spatial knowledge in three different age groups; 8 year old group, 11 year old group, and 19 year old group in a condition that they travelled a route by car. Their spatial knowledge was assessed by asking them to estimate the directions and distances. Travelling and estimation tasks repeated in three sessions and the results were compared. They found that direction estimation were improved in the 11 year old group and 19 year old group from first session to the second session, however, this improved for 8 year old group from the second session to the third session. However, the distance estimation improved only in 19 year old group.

2.4. The means of spatial knowledge acquisition

According to Hag (2001), there are two means to acquire and develop spatial knowledge; one is direct experience of the physical environment, and second is receiving the information from external sources by being exposed to different media, such as physical maps, pictures, mobile maps, and etc. In the navigation process, in order to get to a destination successfully, three stages need to be occurred: 1) people first need to be able to orient themselves in the environment (i.e. they need to know where they are and in which direction they are heading). 2) Then, they need to plan a route to get them to their destination with the knowledge of where their destination is located. 3) Finally, they need to execute the planned route to their destination. In all these three stages in navigation, people refer to the stored spatial knowledge/ cognitive map in their mind, or use the navigational aids such as maps, or combine the both (see figure 2.1).

Figure 2.1. Schematic explanation of stages involved in navigation



There have been different navigational aids that people use. One of the popular ones is physical maps; they have traditionally had considerable roles in conveying spatial information and guiding people through the environment. However, with the recent advent of advanced information technologies, devices (such as mobile devices, cars and etc.) equipped with GPS (Global Positioning System) receivers, such as GPS-based navigators, have become promising tools in guiding people, at least where accurate readings of satellite signals are possible (Shoval and Isaacson, 2006).

Regarding learning the maps, research has shown that maps can help with configurational understanding of the environment, compared to direct experience of the space. This happens because maps, somehow, suggest people the abstract form of the environment, which is very much close to the abstract format of cognitive maps. Having said that, knowledge acquired from maps have a robust relationship with the orientation in which the maps were observed (i.e., orientation-specific), so it is effortful to imagine views from different perspectives (Roskos-Ewoldsen et al., 1998, Sholl, 1988, Thorndyke and Hayes-Roth, 1982). Also, research has demonstrated that using maps in the environments require people to understand the relationships between the map, the surrounding environment, and the self. Liben et al. (2002) showed with their experiments that, doing all these several tasks together is not an easy for children and even for adults.

Regarding the other types of navigational aids, a variety formats of spatial information presentation have been developed, such as verbal navigational directions, static maps, interactive maps, 3-D visualizations, animations, and virtual environments, e.g. see (Montello et al., 2004). Researchers have compared the effectiveness of different presentation formats. For example, Streeter et al. (1985) tested the effectiveness of a route map vs taped verbal instructions for guiding drivers in an unfamiliar environment. They noted that the group used carefully constructed verbal instructions performed better than the route map in travel time and distance and the number of navigation errors. Coors et al. (2005) compared 2-D maps and 3-D visualizations formats of a route instructions on mobile devices. The 2-D maps group located their positions and reached destinations faster than 3-D format group. (Dillemuth, 2005) compared an aerial photograph and a generalized map as representations for a handheld navigational device. They noted that the group used generalized map had faster travel speed and fewer navigation errors than the aerial photograph group. Despite these past attempts in the literature, more empirical research on the effectiveness of different types of navigational aids is still needed.

2.5. The situational context for technologies being used to acquire spatial knowledge

This section discusses the different technologies that people use for acquiring spatial knowledge from a physical environment. Considering the fact that everything man-made is termed to technology (Bellotti et al., 2008), the simplest technology that people use to gain spatial knowledge of the physical environment is physical (paper-based) guidebook and map. The advantage regarding paper-based guide tools is the factor of "adaptability". This factor enables people to select what they want to see as well as finding in-depth information on specific subjects that can help them to make informed decisions (Bedwell et al., 2009). Another type of technology that people use for spatial knowledge acquisition is an Audio guide. This type of technology uses the codes that are in correspondence with the locations in the physical environment. Audio technology has mainly the factor of adaptability (Aoki et al., 2002). Another type of technology regarding spatial knowledge acquisition is Positioning technologies such as GPS, WIFI, RFID tagging. This technology using wireless technology has suggested the technology of location-based services (LBS) such as tourist guides (Abowd et al., 1997, Cheverst et al., 2000). LBS technology, by allowing the visitors to tag their experiences (e.g. photos, and written recommendations) to the locations, provides the users with a system to select their preferences. These systems accordingly can offer suggestions to visitors to enhance their experience of place (Bellotti et al., 2008). Presenting dynamic information is another type of guide technology (e.g. specific events and opening hours). These systems offer more structured physical guidance and narrative to the users (such as scripted, linear audio and video tours on a specific path) (Bedwell et al., 2009). Finally, tactile display systems are another type of technology that people use to be informed about the physical environment during their navigation. The advantage of the tactile system is that they do not interfere with the visual and auditory sense. The table below summarises the information regarding these technologies.

Table 2.1. Wayfinding technologies

Technologies	**Advantage**	**Reference**
Paper-based maps and books	enabling people to select what they want to see as well as finding in-depth information on specific subjects that can help to make informed decisions.	(Bedwell et al., 2009)
LBS (GPS and WIFI)	by allowing the visitors to tag their experiences (e.g. photos, and written recommendations) to the locations, provides the users with a system to select their preferences.	(Abowd et al., 1997)
Audio guide	This type of technology uses the codes that are in correspondence with the locations.	(Aoki et al., 2002)
Dynamic information	These systems offer more structured physical guidance and narrative to the users (such as scripted, linear audio and video tours on a specific path).	(Bedwell et al., 2009)
Tactile displays	The advantage of the tactile system is that they do not interfere with the visual and auditory sense.	(Heuten et al., 2008)

Dynamic information systems are interactive maps. Such as Cyberguide (Long et al., 1996) or LoL@ (Pospischil et al., 2001), that show the user's position on an interactive map allowing the users to orientate themselves in an unfamiliar environment. In these systems, pictures from the main landmarks of the site can be combined with the maps. These interfaces are often used on mobile phones.

The advantage of audio guide systems is that using the head-mounted- displays allow people to free their hands from holding a device. The researchers have studied the use of sound for people's guidance within the place. These systems were initially designed to assist people with visual problems and later were developed to be used by a wider group of people. Trekker (Heuten et al., 2008) is a wayfinding tool that is designed to assist people who are visually impaired. The tool relies on speech in- and output. The users for using this tool should concentrate on the auditory output in order not to miss any important information. Also, they need to transcribe the spoken directions into the actual world. This involves users' interpretation, which can make stress for the users. The users need to process multiple auditory stimuli in parallel since speech produces serial information. Audio GPS attempted to solve this problem by demonstrating the information in an ambient (Holland et al., 2002). The information presented by AudioGPS has an orderly manner; the directions to the destinations are continuously displayed using a spatial non-speech sound (e.g. second junction). The main problem with auditory systems is that the important sense of vision is

being limited. Most of wayfinding mobile applications use both visual and sound displays. These applications require the users' attention for interpreting the sound and visual displays. This can interrupt critical task such as walking in a crowded place or riding a bike while using the interfaces. Tactile systems use tactile displays for guiding the user along a path. For example, Rotating Compass (Rukzio et al., 2005) brings together a visual compass with the vibrotactile display of a mobile phone. The phone starts vibrating whenever the correct direction is presented. The Feel- Navi application consists of the ActiveBelt technology (which is a belt-type tactile display consisting of eight vibrators) and a navigation system. The user's destination is presented by activating the vibrator most closely by pointing into the direction of the user's destination. Tactile systems can provide the users with a more non-intrusive direction presentation (Van Erp et al., 2005). The table below summarises the problems that people encounter with while using different navigation tools.

Table. 2.2. User's problems with wayfinding systems

Problem	Explanation	System types	References
Structured interaction displays	The logic of the system should be understood and replaced with naturally relying on the information interpreted by the brain.	All systems	(Heuten et al., 2008)
Applicable by highly interpretation ability from the user	These applications require the users' attention for interpreting the sound and visual displays. This can interrupt critical task such as walking in a crowded place or riding a bike while using the interfaces.	Visual systems Audio systems	
Distracting	Displays need the user's attention while they are interpreting the visual presentation in the actual world.	Visual systems Audio systems	
Visual sense occupied by other senses	The main problem with audiotory systems is that the important sense of vision is being limited.	Auditory systems	

In using all these applications and interfaces, the environment plays a huge role in how these devices will be used. When people are moving, it is difficult for them to concentrate on both physical environment, and the displays simultaneously. Consequently, if there is a breakdown in the procedural knowledge (mental model/ virtual/reality), the wayfinding task becomes inefficient. Another important characteristic of mobile wayfinding is the context of the users while moving. Context-dependent navigation is vital to a mobile user. Different situations can impair the users' ability to utilize navigation tools while on the move.

Among these applications, mobile maps using GPS are being widely used for navigation. Studying mobile maps are therefore the focus of this study. The table below demonstrates the factors are influential on the mobile map users in navigation.

Table 2.3. factors affecting the mobile map users in navigation

Skills and Experience	Mode of movement	Time of day/year	Reason of moving
• Map experiences • Ability in Abstraction (reading the north) • Environmental knowledge • Familiarity with features of map • Age, and health	• car • bicycle • pedestrian	• Daytime or nighttime (some objects cannot be seen at night) • Season (restricted visibility due to the features in the environment) • Rush hour • Path restrictions	• Tourist tour • Shortest, fastest, most scenery, specific distance, or safest route • Direct path to destination

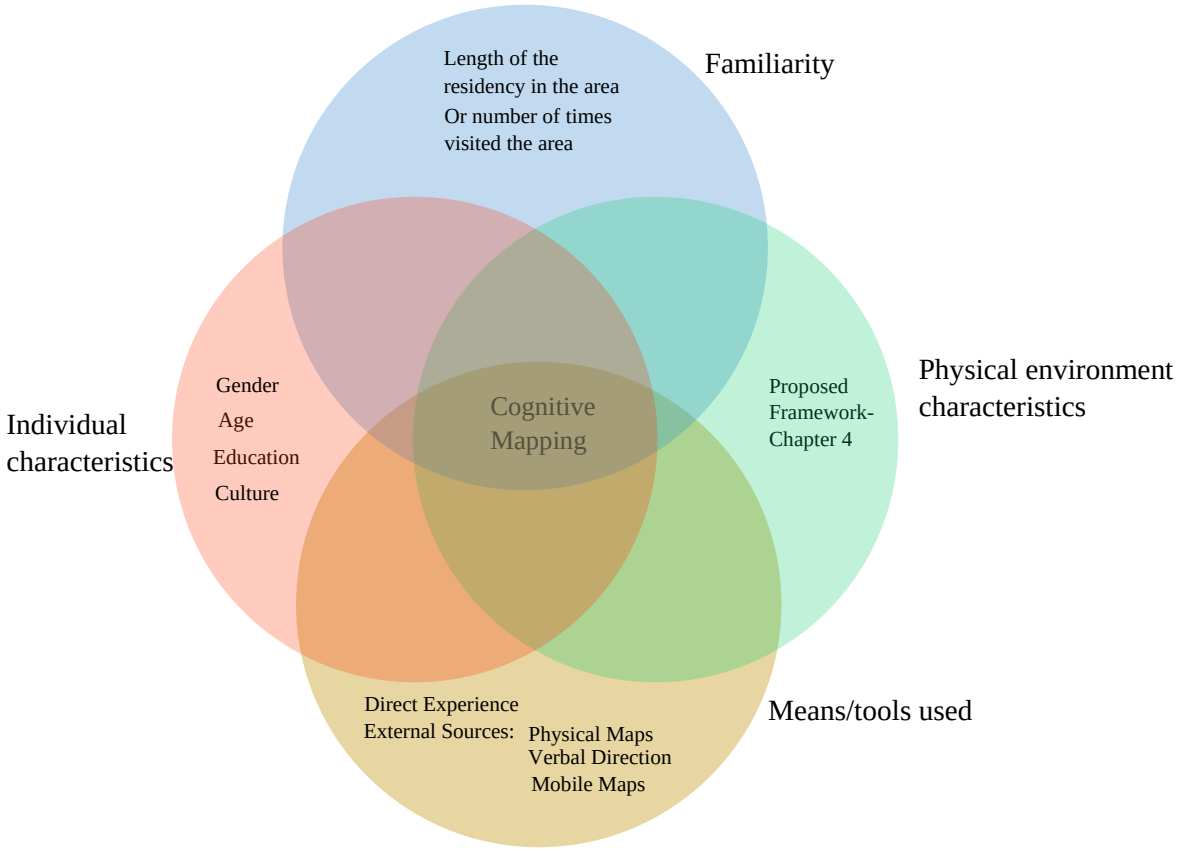
2.5. Spatial knowledge acquisition by mobile maps

Research has shown that mobile navigation systems are not very effective tools in helping people to acquire spatial knowledge. Münzer et al. (2006) compared the spatial knowledge acquired by people who used a hand-held computer-based assistance (which could indicate the to-be adopted direction from the current position of the user) to those who used physical maps for navigation in a real environment (zoo). As they mentioned, depending on the learning experience, people acquire different forms of knowledge of the physical environment. Route knowledge is the knowledge of places/landmarks and the routes that attach them, and survey knowledge specifies an understanding of the spatial relationships between locations. Most of the people first acquire route knowledge, when exploring an environment merely by navigation (i.e. without any assistance such as a map). Münzer et al. tested their participants' route knowledge and survey knowledge of their study site. They found that participants who used physical maps presented perfect route knowledge and good survey knowledge. However, computer assisted participants were not very successful in acquiring route and survey knowledge; they showed poor survey knowledge and nearly good route knowledge. Likewise, Krüger et al. (2004) studied the effects of mobile pedestrian navigation systems on the development of route and survey knowledge acquired by people in an experiment. They illustrated the similar results to Münzer et al. and reported that people who used mobile maps for navigation could not build up a strong survey knowledge of the study site. In another study, Ishikawa et al. (2008) compared the spatial knowledge acquisition of GPS-based navigation systems users, physical map users and self-experience users in an urban environment employing sketch map drawing test as a method. They measured the sketch maps in terms of topological accuracy through counting for each participant the number of routes that depicted all the turns in the correct directions and sequences. They stated that GPS users had a poorest topological accuracy of the area that they have been through. Willis et al. (2009) noted that people navigating with mobile maps were less accurate in drawing the sketch maps of the studied area and also had poor configurational knowledge. They also found that mobile map users were poor in estimating the distance travelled or the cardinal directions of landmarks they passed by.

2.6. The main contributors in spatial knowledge acquisition

As discussed above, according to the theories regarding the spatial knowledge development, there are, at least, four main contributors involved in forming spatial knowledge or cognitive maps: individual characteristics, degree of familiarity with the physical environment, physical environment itself, and the means of spatial knowledge acquisition (figure 2.2). As Golledge (1987) stated, cognitive mapping development is a way to structure, make sense of, and confront with the complexities of environments that are external to brain. So the development of cognitive mapping has a robust relationship with environmental and individual factors. Indeed, the degree of familiarity with the environment is an important factor in human cognitive mapping development. As it was mentioned above, in the theories of spatial knowledge development, as people get to know an environment better, they will conceive a better cognitive map of it. Moreover, individual characteristics and abilities have an essential role in this process. Some people can find the destinations and directions easily, while others get lost so often. However, the individual ability and competence is not the focus of this study. Finally, the way with which people acquire spatial knowledge is an important factor; people may experience an environment directly, or use some types of external sources, such as physical maps, mobile maps, or a combination of them. In the experiments of this study, the familiarity degree and individual abilities in spatial knowledge acquisition are tightly controlled in order to study the effects of spatial factors of physical environment and the means of spatial knowledge acquisition (direct experience vs mobile maps) on spatial knowledge acquisition. In the next section, the relation of physical environment and its properties on spatial knowledge acquisition is discussed.

Figure 2.2: The Main Contributors in Cognitive Mapping- Author's Diagram



2.7. Spatial knowledge acquisition and physical environment

One of the main contributor in spatial knowledge acquisition or cognitive mapping is physical environment, which is the focus of the study in this thesis. Physical environment refers to any natural or man-made features of the environment. They can limit and/or facilitate people's environmental behaviour, such as, navigation (Pastalan and Carson, 1970). In this study, the physical environment specifically is referred to the man-made/built urban environment.

Cognitive maps are the internal representation of the physical environment; people abstract the physical environment into cognitive representations in order to store the spatial information quickly and efficiently. Indeed some specific elements are more imageable, or can be stored easily in people's mind than others. Kevin Lynch (1960) suggested five imageable elements that comprise people's cognitive maps. He identified these elements by interviewing people and analysing their sketch map of three different American cities. These elements are landmarks, paths, nodes, edges, and districts. After Lynch, other researchers

tested Lynch's findings and confirmed the results, e.g. see (Appleyard, 1969, Appleyard, 1970, De Jonge, 1962, Francescato and Mebane, 1973, Gulick, 1963). The importance of these spatial elements in forming the cognitive maps varies in different studies, Table 2.1 demonstrates these differences.

These spatial elements can be defined as follow:

1. Landmarks are a reference point for the traveller/observer; these points have distinctive characteristics that contrast with background information. For example, tall buildings, historic buildings, buildings with distinctive colours (e.g. parliament building, and Big Ben in London, Washington Monument in Washington D.C.).

2. Nodes are strategic points in the physical setting which a traveller/observer can entre to. They are the rigorous foci to and from which people travel. They are mainly junctions, where there is a break in transportation, a crossing or convergence of a number of paths, or moments of the shift from one structure to another. Examples are a traffic square, civic square, etc.

3. Paths are the channels in which a traveller/observer moves usually, occasionally, or potentially. They can be streets, walkways, transit lines, canals, and railroads.

4. Edges are linear elements that act as boundaries between two phases and are linear breaks in continuity: shores, railroad cut, edges of development, and walls.

5. Districts are medium-sized subsections of the city/neighbourhood. People may entre it and feel "inside of". They can be a business centre, campus, or a residential neighbourhood.

Table 2.4: Summary of the research identified the important elements of the sketch maps drawn by their participants and the degree of their importance. Adopted from Long and Baran (2012)

Researcher(s)	Cities studied	Number of Participants	Important Elements				
			Land-mark	Node	Path	Edge	District
K. Lynch (1960)	Jersey City, Los Angeles (United States)	60 (Professional, managerial)	●	●	●	○	●
D. de Jonge (1962)	Amsterdam, The Hague, Rotterdam (Netherlands)	72 (Wives of white-collar workers)	●	●	●		○
J. Gulick (1963)	Tripoli (Lebanon)	35 (students, upper middle class)		○	○		●
H. Klein (1967)	Karlsruhe (Germany)	1118 (Residents)	●	●	○		
T. F. Saarinen (1969)	Chicago (United states)	72 (students, workers)	●		●	○	●
D. Appleyard (1969)	Giudad Guayana (Venezuela)	320 (Residents from selected settlements)		○			●
D. Stea and D. Wood (1970)	Mexico City, Puebla, Guanajuato, San Cristobal las Casas (Mexico)	769 (Residents, students)	●	●	●		○
D. Francesco and W. Mebane (1973)	Milan and Rome (Italy)	183 (residents)	●	●	○	●	
X. Yan (1990)	Beijing (China)	432 (residents, professional)	●	○	●	●	●
K. Lynch (1990)	Theoretical arguments			●	●		●
A. B. Jacobs (1993)	Theoretical arguments				●		

Notes: ○ Important element ● Very important element

The physical environment can be recognised and remembered because of some characteristics of the physical environment, such as the height, the significance, unique architecture of a building, or the width of a path, or the colour of its pavement and so on. Such properties of the physical environment are 'elemental', and their characteristics can be understood by only being present at the place. However, another property of the physical environment which can be only learned by moving within the physical environment is concerned with relation and organisation between places/ elements of the physical environment. The former, elemental properties, are termed to *discrete properties* (or, discrete elements) and the latter as *relational properties* (or, relational elements) (Haq, 2001). Both types of properties comprise the cognitive maps.

There are many physical-spatial characteristics of both discrete properties and relational properties that are influential on people's cognitive map or spatial knowledge. These characteristics have been found through empirical studies and are suggested by different researchers. As in this thesis, the focus is particularly on studying the effects of the physical environment on spatial knowledge acquisition, before going through the experiments of the study, a framework is suggested that synthesises comprehensively all characteristics of both discrete properties and relational properties that are thought to be influential on spatial knowledge acquisition. This proposed framework is elaborated in the next chapter (Chapter three).

2.8. Spatial knowledge acquisition by mobile maps in the physical environment

Section 2.5 discussed the studies concerning the effectiveness of mobile maps in acquiring spatial knowledge. The key element of all these studies is their attempts to examine the effects of different types of mobile navigation systems with different types of information modalities (e.g. audio, text, map, and etc.) on the user's spatial knowledge acquisition. These studies are supported by using many empirical tests and observations in different physical settings. Nonetheless, there is a lack of study on the relationship between the physical environment and spatial knowledge acquisition by mobile navigation systems. In using mobile maps in navigation, there is an interactive transaction between three main contributors, namely, individuals, mobile maps and physical environment. However, investigating the relationship of the physical environment with this transaction has been often overlooked. The study by (Li (2006)), which is one of the few studies that looked at the relationship between the use of mobile maps and physical environment, emphasises that the

spatial layout of the physical environment and wayfinding difficulties people encounter in the physical setting affect the way and amount of people's use of mobile maps. As part of the study, it was demonstrated that people tend to use mobile maps much more at the decision points, the destinations where the next task needed to be planned, and only little usage for re-assurance along the route. In this thesis, given the fact that the physical environment is an important determinant in forming people's spatial knowledge, the effects of physical environments on spatial knowledge acquisition of people using mobile maps for navigation are studied; this thesis mainly focuses on how is the association between physical-spatial features of paths, nodes, and landmarks in the real world and the spatial knowledge acquired from these elements by mobile map users.

2.9. Spatial knowledge acquisition and urban design

This section discusses the spatial knowledge acquisition from the perspective of spatial design disciplines (i.e. architecture, landscape design, planning, and urban design). The notion of legibility, wayfinding and the design factors that are influential on these two concepts are elaborated in this section.

2.9.1. Legibility

In architecture, urban planning, and urban design, the notion of spatial knowledge acquisition and the clarity of the image of the place has been received considerable attention. In these disciplines, the term 'legibility' is referred to the extent to which the physical environment can be comprehended.

Lynch is his book '*The Image of the City* (Lynch, 1960)' defined "legibility" as the quality of physical environment which is related to the degree to which people can understand its structure, navigate themselves within the place, and make sense of the environment. He also refers to legibility as the perceptual clarity of a physical environment or the ease with which its parts can be recognised. Also, Lynch (1960) introduced the term 'imageability' as the quality in a physical object that provides it with a high probability of evoking a strong image in any given observer. Lynch uses these two words interchangeably as there is not a big distinction between them. However, legibility is referred to the more immediate perceptual accessibility while imageability is specified as more a deeper emotional, personal quality.

The importance of both imageability and legibility qualities goes beyond the beauty of the physical environment. Lynch et al. (1995) stated that legibility is the essential precondition of beauty. They also mentioned that the discourse of urban aesthetics was deliberated from

realm of sentimental values inherent in concepts such as the picturesque or the aura of authenticity 'from City Beautiful to the Legible City' by emerging the concept of legibility and the methods for evaluating it.

Lynch proposed five physical elements that constitute people's image of the city (or their mental map): Paths: These elements are the channels of an individual movement

Nodes: These are the strategic points/ decision points in the physical environment that can be entered (e.g. intersections of multiple paths)

Landmarks: these elements are points of external reference, and they can be recognized because of their distinctive features or functions. Landmarks are often used for orientation in the city

Districts: districts are areas of the city that have their own character and can be entered by people

Edges: Edges are mainly articulated linear elements (other than paths) that cannot be entered (e.g. shores or walls)

The nature of these elements is relational, and their fundamental value lies in their ability to integrate different parts of the city to build up a coherent image of the city. Lynch emphasises that informing people's image of the place, not only functional elements such as paths and landmarks should be understood, but also obstacles, barriers, and borders are essential in establishing a mental image of a place.

Following Lynch, Wiseman (1981, p. 189) defined legibility of the environment as "the extent to which it facilitates the process of way-finding". The definitions of legibility indicate that the characteristics of the physical environment are influential on the accuracy of the people's image of the place. Wiseman undertook a series of experiments in ten different university buildings and tested the effects of legibility of the buildings from his research participants. Wiseman argued that the legibility of the environment in complex buildings is related to a number of physical variables such as signs and numbers, architectural differentiation, visual access, and plan configuration (1981). He demonstrated that people find their destinations easier in a more legible setting. In the same vein, Downs and Stea (1973) pointed out that legible settings show more coherent and orderly pattern. According to their findings (Downs and Stea, 1973), people's sketch maps of the legible settings are more complete and accurate than those are less legible. The coherent and orderly patterns in the

physical environments which are the results of a hierarchical relation between urban elements can be well-understood by people since the human's brains work in a way that analyses these type of patterns easier and store them faster in the long-term memory (Baskaya et al., 2004).

2.9.2. Wayfinding and legibility

The notion of wayfinding cannot be separated from the concept of legibility. The previous literature on legibility indicates that the legibility of an environment is vital to people's wayfinding (i.e. human spatial problem solving). Wayfinding has been defined and discussed by different researchers. Golledge (1999, p. 6) stated that "wayfinding is the process of determining and following a path or route between an origin and destination. It is a purposive, directed, and motivated activity. It may be observed as a trace of sensorimotor actions through an environment. " According to Carpman and Grant (1993, p. 66) "wayfinding refers to what people see, what they think about, and what they do to find their way from one place to another…Wayfinding involves five deceptively simple factors: knowing where you are, knowing your destination, knowing and following the best route to your destination, recognizing your destination upon arrival, and finding your way back." Similarly, Passini (1984) described that wayfinding is a process which consists of information processing, decision making, and decision execution. There are two common points in all of these definitions: a) the term 'wayfinding' is commonly used to refer to the act of finding the destination itself or the paths leading to an individual destination. b) Wayfinding is an 'individual's ability' to navigate and find a specific destination within an environment.

According to Haq (2001), there are two general models regarding wayfinding. First, the physical environment affects people's spatial cognition and then the spatial knowledge acquired in this process influences the subsequent wayfinding act. Many researchers, such as Wiseman (1981), and Passini (1984) demonstrated this interaction between the physical environment and wayfinding. In contrast, a few researchers accept the theories of ecological perception which are introduced by (Gibson, 1979). They believe that the environment directly acts upon people's wayfinding behaviour without having a cognitive process (McGrath et al., 1983). Despite the major differences between the two models, both of them reveal that wayfinding and spatial knowledge acquisition take place through moving within the physical environment.

In the wayfinding process, there is a continuous interplay between an individual's wayfinding act and the physical environment. Much research has been conducted to investigate and understand the wayfinding process and techniques to facilitate wayfinding performance (Gårling et al., 1995). Researchers have shown that the legibility of the physical environment contributes to the ease of wayfinding within the place.

Lynch was criticised for overplaying the importance of way-finding, he discussed the importance of legibility and having a clear image of the place in wayfinding, but he never demonstrated it. What would people care if they have a vivid image of a place? Would 'not people be delighted by serendipity and mystery during their movement? However, Lynch argued that his assumption was supported by the data collected during the interviews in his study. According to his results, he deliberated that people prefer legible environments to confusing ones.

The next section discusses the factors of the physical environment that contribute to the legibility and ease of wayfinding.

2.9.3. Legibility factors in buildings and urban environment

The physical environment can facilitate/limit people's navigation and orientation to some degree, depending on the characteristics of the physical elements and the relational characteristics between the elements. In this regard, the concept of legibility introduced by Lynch has been fundamental in urban design, planning, architecture, and environmental design fields for a few decades. In this vein, he argued that a legible city could facilitate peoples' orientation in the city. There is a long body of research that has identified the characteristics of the physical environment that contribute to the legibility of the place. This section elaborates these factors.

Indeed, the history of cities conveys that people have always been looking for a hierarchical space organisation and the street pattern in building their cities, for example, a closed order (the walled city) in the Middle Ages; a structured order in the Renaissance; a functional order in the Industrial era; and an open order in our modern era (Curran, 1983). Today, the research in environmental psychology demonstrates that humans' brains inherently prefer spatial schemas that are orderly organised (Canter et al., 1974). People tend to make a clear and accurate mental map of the places that have a clear organization (Cohen, 1985). Churchill (1962) stated that "legibility develops from a grand scheme like the grid. Legibility requires attention to topography, variety in types and sizes of streets, promoting a certain degree of homogeneity within a small area but varying or differentiating in styles from area to area". Also, Devlin (2001) indicated that "when we describe a building, neighbourhood, or city as legible, we just say that we can 'read' it or understanding its relationships and that they make sense and create a pattern that enables us to find out a way" (p. 192).

The legibility of the elements of the physical environments is the necessary requirement to appreciate the spatial organisation of the place. For example, in a building, the legibility of the architectural elements, such as entrances, horizontal and vertical circulation, and landmarks enable people to understand the spatial organisation of the building. A physical environment cannot be understood if it does not have a clear spatial organisation. Such a place cannot help with wayfinding since it has a low legibility factor. Arthur and Passini (1992) stated that spatial organisation has to be communicated to the place users in order to help them to find their ways within the physical environment. Moreover, another factor that can help people to understand the physical environment is signage. Passini (1984) pointed out that all details related to signage (e.g. the graphics of signage system, the choice of lettering,

the contrast created by black, white, and coloured elements; the size, the position and illumination of a sign) can contribute to comprehension of the signage and consequently to the legibility of the place.

Weisman 1981 found that 'simplicity' of the floor plan configuration affects the legibility degree and is a strong predictor of self-reported wayfinding performance. According to his research, he proposed that four kinds of environmental information are essential in legibility: (a) visual access to the landmarks within or exterior to a building, (b) the degree of architectural differentiation between different areas of a building that can aid recall and wayfinding (c) the use of signs and room numbers to provide identification or directional information, and (d) building configuration, which can influence the ease with which one can comprehend the overall layout of the building.

People find their ways within a complex setting by understanding the spatial entities (i.e. elements of place and the spatial organisation between them) and make the mental map of the setting. People can only map these spatial entities if they are distinctive and can be distinguished from their surroundings (Arthur & Passini, 1992). Distinctiveness can be achieved by architectural form and volume of the space, the architectural details of the elements, such as light, colours, and graphics (Arthur & Passini, 1992).

Passini et al. (1998) elaborated the importance of distinguishing a zone; they emphasised that a zone with a strong character can form a certain spatial zone as well. It is assumed that large-scale environments are too extensive to be perceived in their entirety from any one location, so brain tends to break them down to smaller zones. Wright et al. (1993) state that finding a specific location in many modern complex buildings can be problematic; in the buildings that corridors on different floors look very alike. In such buildings, information regarding specific locations, spatial relationships among those locations, and the locations in relationship to the rest of the building are not easy to be appreciated by the users. Passini et al. (1998) stated that a wayfinding task is affected by two major physical factors: the layout of the setting and the quality of the environmental information. The layout is defined by its spatial content, its form, its organization, and its circulation. Environmental information is the architectural and graphic expression of information necessary to solve wayfinding problems.

Regarding the buildings in urban environment, Evans et al. (1982) report that the ability of people to recall a building and its location in an urban context can be attributed to a series of factors, including building form, architectural style, accessibility, the number of persons

moving around the building (i.e., crowd), and the size of the building. Moreover, in this vein, Lang (1987) states that colour can help with the differentiation between elements in a setting and between settings themselves. In order to make the appreciation of the elements easier, the elements can be of a colour that contrasts with their backgrounds. However, large areas with bright colour can fatigue the eyes and produce afterimages, particularly, when there is a brightness variation in the surfaces. Regarding the colour, the strong contrast attracts the eye, however, too many eye-catchers may also result in confusion.

The form of a building's volume affects the legibility of the building and the wayfinding within the building. The form of a building's volume can help the users to understand the internal organization and circulation system of the building. Circulation system of the building is the key factor that forms the spatial organisation of the building; it is the space that people move within, find their destinations within, and make their wayfinding decisions (Arthur & Passini, 1992). The overall configuration of the layout is therefore influential on people's clarity and image accuracy of the building as well as the ease of wayfinding within the building. The overall configuration of the layout can be characterised by its complexity degree. In the research carried out by Weisman (1981), the participants, who judged the layout of the setting complex, reported being lost more often in the test buildings, which were ten different university buildings. This research showed that the effect of complexity on wayfinding is on both the participants who were new to the buildings and those who had high familiarity with the place. Bronzaft and Dobrow (1984) propose that simplicity and regularity of floor plan contribute to people's comprehension of the layout of the building. Similarly, O'Neill (1991) showed that the complexity of a floor plan form influences wayfinding performance. He demonstrated that even small increase in plan complexity can have a significant effect on people's wayfinding performance. The form of the circulation system may not be visible to the users of a building. However, the buildings which are organised around an open core provide the users of the setting with a better visual access to the circulation system of the building and help people to understand the building well (Arthur & Passini, 1992). The architecture of the building can convey the circulation system of the building and make it easier for people to build a mental map of the setting. In other words, The well-articulated buildings communicate their spatial organisation of the setting. A well-articulated building put its users in possession of valuable wayfinding information (Arthur & Passini).

2.10. Conclusion

This thesis aims to study spatial knowledge acquisitions of people who use mobile maps in an unfamiliar urban environment as well as the association between physical environment and spatial knowledge acquisition of people who navigate the environment by using mobile maps. So the main objectives of this chapter were twofold. Firstly, it aimed to provide a theoretical basis for the aims of the thesis. To this end, this chapter discussed the theories of spatial knowledge development, and all the factors involved in spatial knowledge acquisition, including individuals' familiarity with the site, individuals' characteristics, physical environment characteristics, and means of spatial knowledge acquisition, for example, mobile maps, physical maps, and etc. (see figure 2.3)

Figure 2.3. A schematic diagram representing the relationships between physical environment, spatial cognition, personal experiences, and spatial behaviour (navigation)

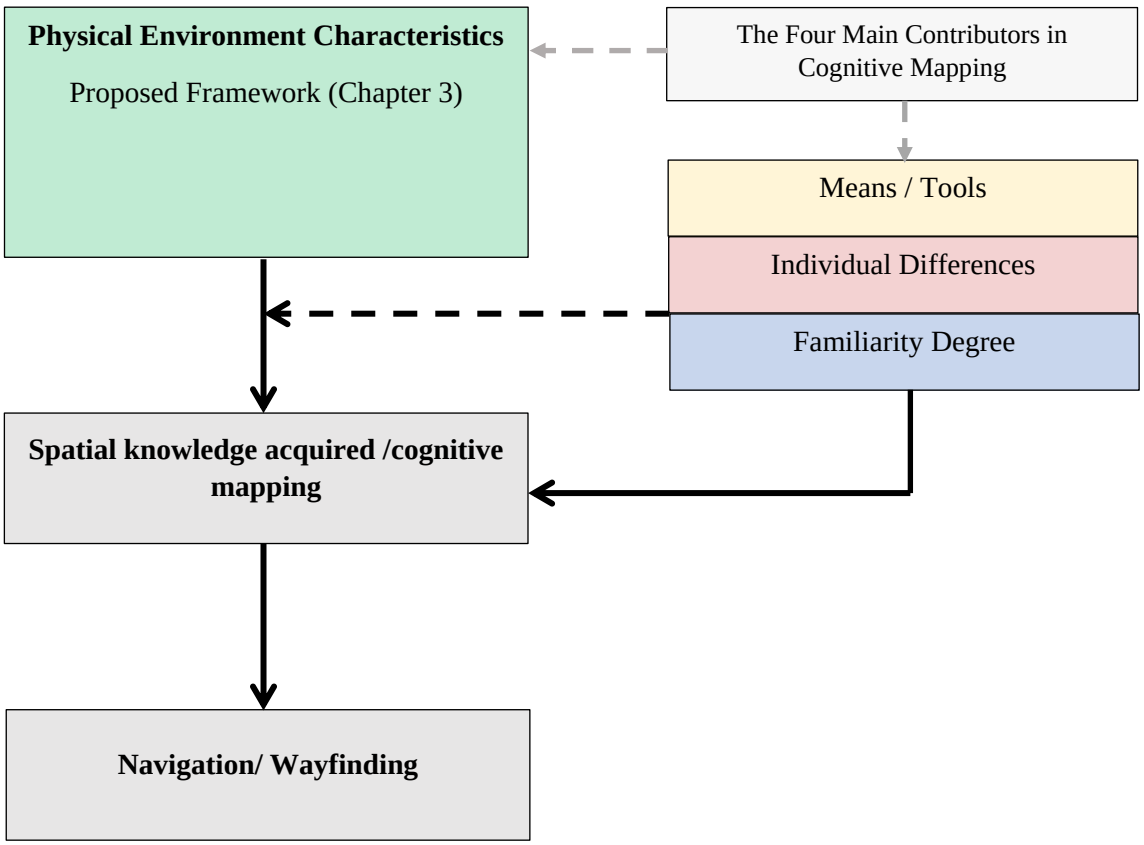
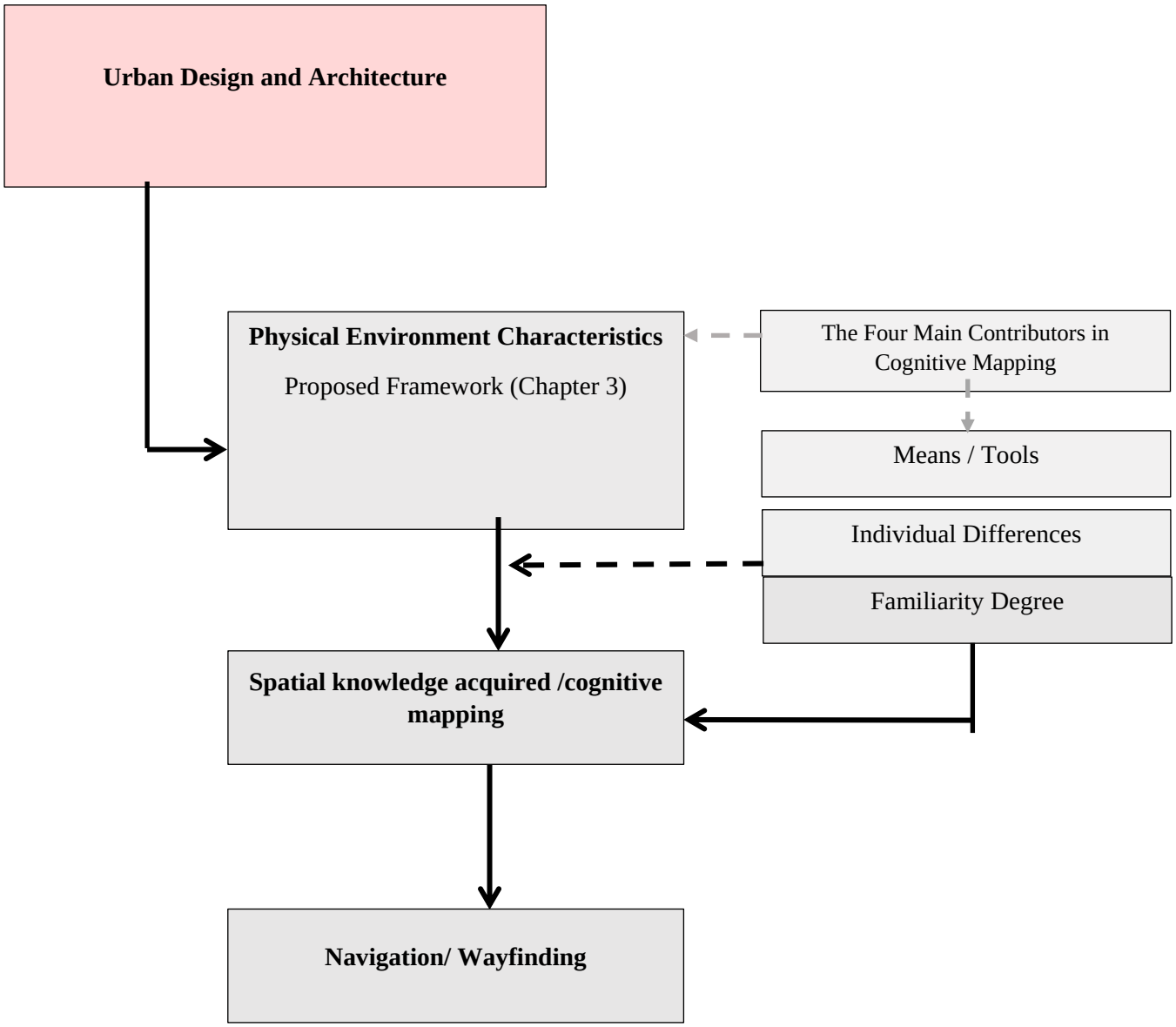
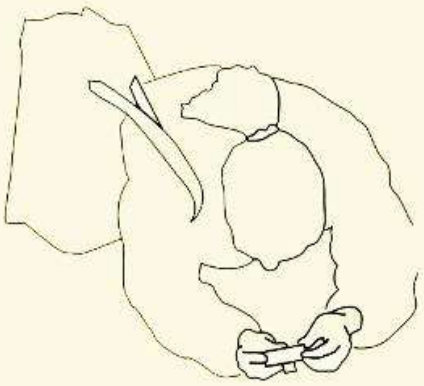


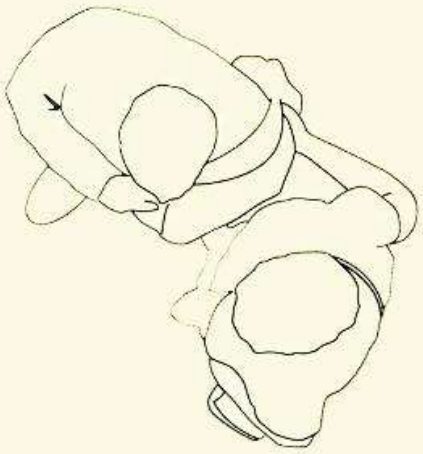
Figure 2.4. A schematic diagram representing the relationships between urban design and other factors involved in spatial knowledge acquisition and navigation



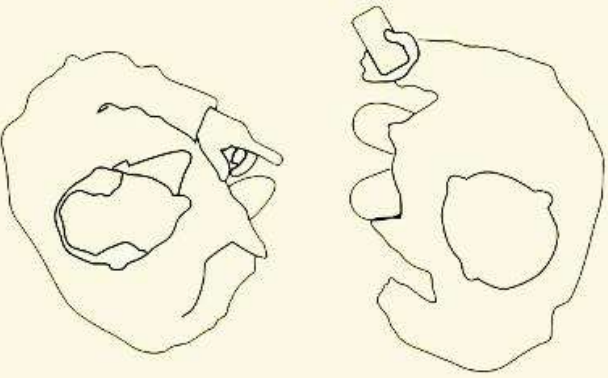
Secondly, this chapter aimed to provides a theoretical justification for studying the effects of the physical environment on spatial knowledge acquisition of people who use mobile maps for navigation. To this end, the chapter specifically discussed other relevant studies which have investigated the spatial knowledge acquisition of people who use GPS-based systems for navigation. The chapter then deliberated the importance of physical environment on spatial knowledge acquisition of people who use GPS-based systems for navigation, which has been overlooked in previous studies. So this thesis will address this gap as one of its main aims.

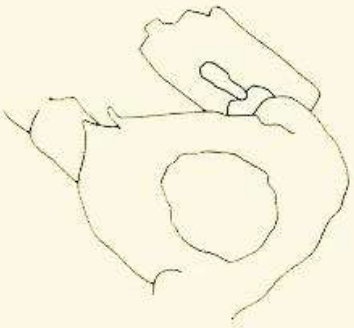
In order to study the effects of the physical environment on spatial knowledge acquisition of people who use mobile maps for navigation, it is necessary to understand how its spatial factors affect people's spatial knowledge acquisition. To do so, there is a need to have the list of spatial factors that are evident to have an influence on spatial knowledge acquisition. Therefore, the next chapter, by reviewing the literature, will demonstrate the spatial factors that affect spatial knowledge acquisition. These factors will be introduced in a framework in order to be used in this study. This thesis will further examine the relationship between the acquired spatial knowledge of the participants of this study and the spatial factors in this proposed framework.

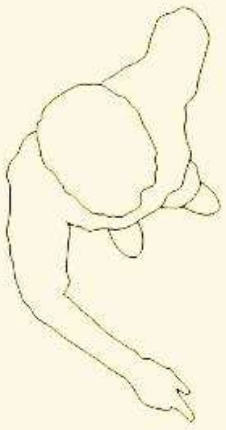




3. Proposed Framework: synthesising the spatial factors involved in spatial knowledge acquisition







3.1. Introduction

One of the aims of this thesis is to study the effects of physical environment on spatial knowledge acquisition of people who use mobile maps for navigation. As discussed in chapter 2, there has been a little study on this matter. In order to investigate the effects of physical environment on acquiring spatial knowledge, it is necessary to understand the effects of the spatial factors of the environment on people spatial knowledge acquisition. This chapter therefore aims to present these factors. To this end, this chapter proposes a framework which synthesises the spatial factors affecting spatial knowledge acquisition. This thesis will further examine the relationship between the acquired spatial knowledge of the participants of this study and a series of spatial factors in this proposed framework.

3.2. Synthesising the spatial factors affecting spatial knowledge acquisition

Research has long acknowledged that physical-spatial features of the properties of the environment, which are termed to spatial factors of the environment, have a considerable effect on people's spatial knowledge acquisition. Although many researchers have suggested different spatial factors affecting spatial knowledge acquisition, there is still a need for further research on how to incorporate all these factors into a comprehensive framework. Having such a comprehensive framework can offer researchers a full picture of all spatial factors together affecting spatial knowledge acquisition. Developing and using the framework compounding spatial factors can then help to ensure that all relevant factors are accounted for in any particular evaluation and analysis, thereby enabling researchers to collect all the required data to analyse the physical environment in relation to spatial knowledge acquisition. Such framework can specifically provide urban designers/planners with an effective tool with which they can evaluate the physical environment and their spatial design in relation to people's spatial knowledge acquisition.

Literature has suggested several frameworks that somehow incorporate the spatial factors affecting spatial knowledge acquisition. However, all of them focus either exclusively on a specific element of the environment or overall characteristics of the environment where the successful approach for studying a complex environment is considering all aspects of a system, namely overall features, exclusive characteristics of its elements and relational aspects between them. Reviewing the literature on spatial factors, this thesis then proposes a more comprehensive framework which incorporate the spatial factors influencing spatial knowledge acquisition into two sub-categories: 1) *elemental factors* of the physical environment, and 2) *overall factors* of the environment. The former encompasses the

physical-spatial characteristics of the discrete elements/places as well as the relation between them, while the latter is concerned with the overall features of the environment.

3.3. Other frameworks and their proposed set of spatial factors

Research suggests different spatial factors that are closely linked to spatial knowledge acquisition, such as landmark positions along the route, the form and length of routes, the shape and form of landmarks, the configurational complexity of the environment, the number of turns along a route, and the number of intersections linked together in a given setting. These spatial factors are in different types and can be classified into different categories. Researchers have proposed several classifications of spatial factors that affect spatial knowledge acquistion. For example, Weisman (1981) articulates a taxonomy for physical features thought to be influential on spatial knowledge in navigation. These features include: a) visual access between key locations and different places within the setting; b) architectural differentiation between different parts of the building; c) the use of signs and directional information; and d) layout complexity. These factors have also been examined by a number of other researchers (Peponis et al., 1990, Arthur and Passini, 1992, Passini et al., 1998, Wright et al., 1993, Dogu and Erkip, 2000, Cubukcu and Nasar, 2005). Aiming to evaluate the environment in relation to people's spatial knowledge, Passini et al. (1998) define two major categories of spatial factors: the layout of the setting; and environmental information. They state that the physical characteristics of the layout are defined by its spatial content, form, organisation, and circulation. Evans et al. (1982) and Appleyard (1969) focus on buildings and develop a taxonomy of building characteristics corresponding to environmental memory and spatial knowledge, such as the shape, height, and significance of the buildings.

The key elements of these frameworks are their proposed spatial factors, which are suggested based on their original empirical studies. As Peponis et al. (1990) stated, they aimed to develop frameworks based on spatial characteristics of the physical environment by which they can anticipate aspects of spatial knowledge acquisition and navigational behaviour. These approaches were enriched by using many empirical tests and observations. Nonetheless, they lack many other factors that are considered to affect spatial knowledge in other more recent studies. Despite the attempts to propose a range of factors, these classifications do not adopt a holistic approach that can be used to form a systematic and comprehensive evaluation process. Table 3.1 presents the frameworks discussed above along with their proposed spatial factors for evaluating the environment.

Table 3.1: Frameworks with their proposed physical factors influencing spatial knowledge

Researcher(s)	Spatial factors
Weisman (1981)	a) visual access between key locations and different places within the setting; b) architectural differentiation between different parts of the building; c) the use of signs and directional information; and d) layout complexity.
Passini et al. (1998)	1) the layout of the setting: a) spatial content, b) form, c) organisation, and d) circulation 2) environmental information
Appleyard (1969),and Evans et al. (1982)	Building characteristics**:** Size, Shape/complexity, Contour, Colour/texture Movement around the building, Maintenance quality, Signage Style Naturalness, Ease of pedestrian access/ sitting, Movement by the most prominent viewpoint, Proximity to a major decision point, Centrality to the, circulation system, Uniqueness of function (singularity), Use intensity, Building significance

3.4. Towards a more comprehensive framework

The studies concerning spatial factors can be classified into three categories. Firstly, the studies that have taken into account solely the characteristics of one specific element within the setting. For example, Evans et al. (1982) studied the effects of pathway configuration on people's spatial knowledge. They found that the manipulation of grid pathway configuration change people's spatial knowledge. In another study, Haque et al. (2006) developed an algorithm that computes the (shortest) most reliable path in navigation which is more memorable to people. By focusing on intersections in the physical setting, Richter and Klippel (2004) indicated that the level of complexity of an intersection influences people's spatial knowledge. Secondly, some studies have investigated the relational aspects of different elements within the environment. For instance, Omer and Goldblatt (2007) investigated visibility between landmarks as a spatial factor affecting spatial knowledge. Finally, other research has studied the overall features of the environment rather than focusing on one specific element. Peponis et al. (1990), for example, asserted that to improve spatial design, the attention from sole consideration of the elements of the environment, such as landmarks or pathway, should be redirected to the overall characteristics of the environment. The overall complexity of a setting is one of the spatial factors that has received great attention from many researchers (Dogu and Erkip, 2000, Schwering et al., 2014, Li and Klippel, 2016, O'Neill, 1992).

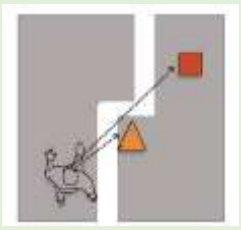
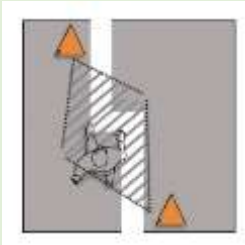
The frameworks discussed in the previous section (Table 1) and other similar ones fail to adopt a holistic approach and include all types of spatial factors. Appleyard (1969) and Evans et al. (1982) have an exclusive consideration in which they merely focused on buildings to develop an approach to evaluate building characteristics. However, Passini et al. (1998), in

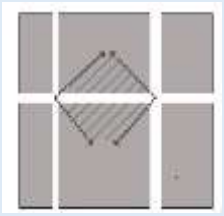
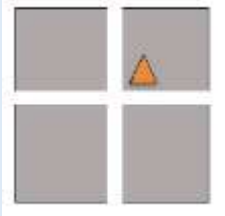
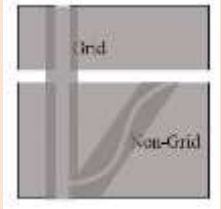
their approach, focused on the overall characteristics of the setting, such as the organisation and circulation of the layout. Weisman (1981) considered some relational aspects between different elements, such as the visibility between landmarks. He also included some overall aspects of the setting, such as the complexity of the layout. Nevertheless, there have been limited studies on how to conduct a more comprehensive evaluation framework for physical environment in relation to spatial knowledge which can fully take account of all types of spatial factors.

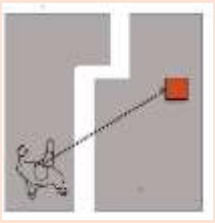
Acknowledging this gap in spatial design studies, this thesis identifies the need for a more holistic framework synthesising the spatial factors affecting spatial knowledge acquisition which can evaluate the physical environment and spatial analysis in relation to spatial knowledge acquisition. To address this gap, we propose an evaluation framework, which aims to develop a systematic approach to evaluate the environment. A set of spatial factors that influence spatial knowledge lies at the heart of this proposed framework. This framework not only relies on the physical characteristics of each element within the setting, but also considers their inter-relational characteristics. Moreover, the framework includes the overall characteristics of a setting. We believe that applying such a framework enables researchers to comprehensively evaluate a physical setting in relation to the development of spatial knowledge.

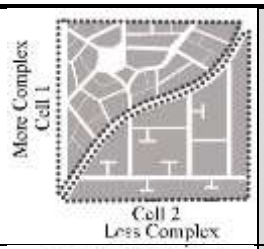
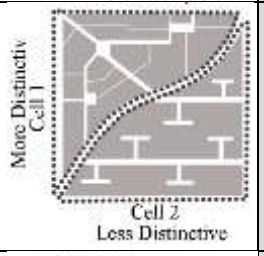
Table 3.2 shows the subsets of the framework within which a physical environment should be evaluated. This framework is flexible in order to accommodate any other possible spatial factors within the related subsets of the framework. The subcategory of ‘elemental factors’ is divided into three categories of 1) landmarks, 2) nodes, and 3) paths. Each category then includes related physical-spatial characteristics. And the subcategory of ‘overall factors’ demonstrates the overall characteristics of the physical environment.

Table 3.2: The set of spatial factors proposed for the framework

		Factors		Diagram	Description
Elemental Factors	**Landmarks**	**Spatial position**	Proximity to the main circulation system		The proximity and centrality of the landmark to the neighbourhood's circulation system (Appleyard, 1969, Evans et al., 1982)
			Proximity to a major decision point		The proximity of the landmark to a major orientation decision point (e.g. street intersection) (Appleyard, 1969, Evans et al., 1982, Lindberg, 1984, Jones, 1972, Heft, 1979)
			Internal/external landmark		Internal landmarks: Those placed in the immediate context of the setting (e.g. a landmark in the street) (Evans et al., 1984b, Lynch, 1960, Westerbeek and Maes, 2013) External landmarks: Those are not in the immediate context, but are visible at the distant line of sight (Evans et al., 1984b, Lynch, 1960, Westerbeek and Maes, 2013)
		Visibility	Visibility to the landmarks		The degree of visual access from origin to the landmarks and the extension of the visual field toward the landmarks (Janzen et al., 2001, Turner et al., 2001, Jiang, 2006, Shah and Miyake, 2005, Omer and Goldblatt, 2007).
			Inter-Visibility between landmarks and other main elements		Visual connectivity between landmarks and with other elements within the setting (Turner et al., 2001, Omer and Goldblatt, 2007)

Elemental Factors		**Form**			Form of the landmark (e.g. All the variables that Evans and Appleyard pointed out; if landmark is a building, the characteristics include: Size, Shape/complexity, Contour, Colour/texture Movement around the building, Maintenance quality, Signage Style Naturalness, Ease of pedestrian access/ sitting, Uniqueness of function(singularity), Use intensity, Building significance) (Appleyard, 1969, Evans et al., 1982).
	Nodes	**Node configuration**	Number of legs (paths)		Number of equivalent choices (paths) that one has at a decision point on the way to find a destination (Richter and Klippel, 2004, Haque et al., 2006; Richter, 2009)
			Grid/ non-Grid layout		The configuration of the node as being grid or non-grid (e.g. non-perpendicular intersection vs perpendicular intersection)(Evans et al., 1984b).
		Spatial position	Centrality to the circulation system		The centrality of the node to the neighbourhood's circulation system (Haq and Zimring, 2003).
		Visibility	Visibility to the node/intervisibility between nodes and other elements		The degree of visual access to the node (Haq and Zimring, 2003).
		Nodes with landmark(s)			Placement of landmark(s) at a node. (e.g an intersection containing historic buildings at its corner(s)) (Klippel and Winter, 2005).
	Paths	**Path configuration**	Grid/ non-Grid layout		Configuration of the path as being in a grid/non-grid pattern (e.g. a straight path v.s a curve path (Evans et al., 1984b).

Elemental Factors			Length		Length of the path (Evans et al., 1984b; Haque et al., 2006).
			Number of turns		Number of turns along a path (it can occur at an intersection as well) (Evans et al., 1984b; Haque et al., 2006).
		Placement of landmarks	Route with internal landmark		Paths containing inernal landmarks (i.e. landmarks along themselves) (Westerbeek and Maes, 2013; Klippel and Winter, 2005).
			Rout with external landmark		Paths with visual access to the extenal landmarks (i.e. landmarks which are not located at the immediate context of the path) (Westerbeek and Maes, 2013; Klippel and Winter, 2005).
			No landmark		Without internal and external landmarks(Westerbeek and Maes, 2013; Klippel and Winter, 2005).
		Spatial position	Integration		Degree of integration of the path in the circulation system (Li and Klippel, 2016).
			Connectivity		Degree of connectivity of the path in the circulation system (Dogu and Erkip, 2000).

Overall Factors	**Complexity**		Degree of complexity of the setting (Dogu and Erkip, 2000).
	Distinctiveness		Degree of distinctiveness of the setting (Dogu and Erkip, 2000).
	Visibility		Degree of visual access within the setting (Dogu and Erkip, 2000). The degree of visual access within a cluster is highly corelated with the portion of open spaces in that.
Elemental Characterstics: Landmarks ☐ Nodes ☐ Paths ☐ Overall Characterstics ☐			
Internal Landmark, External Landmark			

The following sections will discuss the spatial factors proposed for each category introduced in table 3.2.

3.3.1. Elemental Characteristics:

***Landmarks**:*

Regarding the *spatial position of landmarks* in a physical setting, Evans et al. (1984b) suggest that landmarks help to develop a comprehension of place locations. They divided landmarks employed in a navigation process into two types: internal landmarks; and external landmarks. Internal landmarks are those placed in the immediate context of the setting (e.g. a landmark in the street) whilst external landmarks are not in the immediate context, but are visible at the distant line of sight (e.g. the distant view of the dome of a church). They also indicated that internal landmarks are more helpful than external landmarks in comprehending the environment and the navigation process. However, Lynch (1960) pointed out that external landmarks, particularly when they are in line with major roads can enhance the formation of an image of the place. With regard to the spatial position of landmarks, many studies have

suggested that placing distinctive landmarks at decision points affects cognitive strategies for navigation and those landmarks are salient in people's spatial knowledge (Lindberg, 1984, Jones, 1972, Heft, 1979). In their research, Daniel and Denis (2004) asked participants to describe a route as precisely as possible and found that landmarks placed at choice points were remembered better than those that were located elsewhere along the route.

In relation to landmarks, visibility is an important factor in the construction of a cognitive spatial representation. Visibility also enables navigation with the formation of an image of the place being partly dependent on remembering some visual landmarks and creating a spatial relationship between them. The degree to which a person can observe his/her initial location and destination and observe the various landmarks along the route are aspects of visibility that potentially affect the ability to make a cognitive spatial representation and to the quality of spatial knowledge (Shah and Miyake, 2005, Omer and Goldblatt, 2007). Studies also show that the number of visual perspectives and the extension of their visual field affects the cognitive spatial representation of a place (Janzen et al., 2001, Turner et al., 2001, Jiang, 2006). The effects of inter-visibility between the landmarks have been examined in the context of navigation studies that focus on the degree of visual access between them. For instance, Omer and Goldblatt (2007) indicated that there is a relationship between the length of visual chain, visual fields of landmarks, and navigation performance. Indeed, they found that navigation between two landmarks with a short visual chain is easier than navigating between landmarks separated by a long visual chain. Regarding the *built form of the landmarks*, as mentioned earlier, many characteristics that influence spatial knowledge have been examined, such as material, colour, and the historical and cultural significance of a landmark (Evans et al., 1982, Evans et al., 1984a, Lang, 1987).

Nodes:

Nodes, intersections and decision points are challenging elements in forming people's spatial knowledge, particularly when people are unfamiliar with an environment. The *configuration of a node/intersection* affects the image clarity of that node/intersection. The configuration of an intersection affect the intersection complexity. The level of complexity for an intersection depends on the number of equivalent choices that one has at a decision point on the way to find a destination (Richter and Klippel, 2004, Haque et al., 2006, Richter, 2009). When the number of paths increases at an intersection, the ambiguity degree increases

as well. For example, when the intersection is only made of three paths like a ‘T junction’ (two choices), the complexity is less and the probability of making a mistake in route selection is less. This complexity at an intersection has a direct correlation with spatial knowledge (Richter and Klippel, 2004). There are some aspects that decrease the ambiguity level of an intersection such as the placement of a specific landmark at an intersection (Sorrows and Hirtle, 1999, Haque et al., 2006). O'Neill (1991a) used interconnection density as a measure which is known as the average number of nodes linked to every node. His experiments showed that when interconnection density increased, the overall environment setting becomes more complex and less legible and with regard to each node, he suggested that the presence of more options at decision points impairs the ability to construct an accurate spatial image and therefore to navigate effectively. Regarding *spatial position of nodes,* Peponis et al. (1990) indicated that the degree of integration of a node in the circulation system affects people’s spatial knowledge. Using space syntax (Hillier, 2007), research has shown that the intersections that are central to circulation system can be better learned and remembered by people (Kim, 2001, Long and Baran, 2012).

Regarding *nodes with landmark(s),* Klippel and Winter (2005) also analysed the possible locations of a landmark with respect to the physical layout of an intersection and noted that the placement of a landmark at the decision points , which they refer to as a node landmark, can have considerable effects on the legibility of the node and people’s spatial knowledge. They also suggested that nodes which have a landmark(s) in their proximaty can be remembered well by people (Klippel and Winter, 2005).

Paths:

The *configurational characteristics of paths* and path segments affect people’s spatial knowledge. Evans et al. (1984b) studied the effects of the manipulation of pathway configuration and the placement of landmarks along a route in an experimental environment on people’s spatial knowledge. Their work at the Berkeley Environmental Simulation Laboratory found that the grid configuration of a path enhances geographic knowledge. They also showed that a grid structure or layout increased route accuracy in sketch map drawing, however, it did not have a significant effect on the memory of actual place locations. Furthermore, they identified that the length and the number of the turns along a route also affected spatial knowledge. They showed that people better remember the paths that have a less number of turns along them. Sadalla et al. (1980) and (Kahl et al., 1984) also reported

that the greater the number of turns and intersections along the route, the greater the chance of people overestimating distances.

Landmarks can be employed to communicate route knowledge verbally and graphically (Denis, 1997). They are linked with route directions to varying levels, with greater quantities at origins, destinations and notable decision points (Tversky and Lee, 1999, Michon and Denis, 2001). Routes, in terms of their relation to the location of landmarks, can be divided into three categories: routes with internal landmarks; routes with external landmarks; and routes without landmarks. External landmarks aid navigation differently, for example, global orientation, reassurance and confirmation (Klippel and Winter, 2005). Internal landmarks or 'segment landmarks' (Herrmann et al., 1998) are used for reassurance and confirmation. In route description which is in correspondence with spatial knowledge, people tend to use more internal landmarks to describe a route (Westerbeek and Maes, 2013). In other words, people have better spatial knowledge of routes with internal landmarks than those that only have external landmarks. Tom and Denis (2004) even reported that streets are better remembered and described by their internal landmarks than their actual street names.

A spatial configuration of a setting has a spatial hierarchy in which some open spaces are more strategic and more accessible and others less so (Dalton et al., 2012). The strategic or relatively more accessible open spaces tend to attract higher pedestrian movement than other more separated ones (Bafna, 2003). To address the need for analysing part-whole relationships in spatial configurations, Hillier and Hanson (1984) developed Space Syntax methodology to represent and to measure the pattern properties of open spaces in the built environment. Using Space Syntax, the degree of integration and connectivity of a path in the spatial configuration of the setting can be measured. On the other hand, research has shown that there is a strong correlation between the spatial syntax of configuration in real environments and spatial syntax of cognitive maps in spatial cognition (Kim and Penn, 2004). Therefore, as Kim and Penn (2004) demonstrated, the paths that have a high degree of integration in a setting are likely to appear more frequently in people's sketch maps of that setting. In short, the degree of integration of a path in a circulation system is highly influential on people's spatial knowledge.

3.3.2. Overall Characteristics:

This category is concerned with the characteristics of the overall form of the physical environment. Many have identified that *configurational complexity, differentiation and degree of visibility* in an overall form of a setting all affect people's spatial knowledge (Weisman, 1981, Gärling et al., 1986, Abu-Obeid, 1998, Cubukcu and Nasar, 2005, Braaksma and Cook, 1980, Peponis et al., 1990).

In general terms, configuration is the spatial organisation of spaces within a setting and Peponis et al. (1990) refer to configuration as the spatial relationship between spaces in a setting. The overall configuration of a setting is concerned with spatial knowledge and the ease of navigation. Researchers treat the overall configurational comprehension of a setting as an ultimate stage of spatial cognition and spatial knowledge development. If a setting does not have a clear spatial organisation, it tends to be not understood, as it does not easily convey the spatial information of the setting to the user (Dogu and Erkip, 2000). Complexity is the quality of the plan configuration and it has been maintained that configurational complexity is the primary effect on people's spatial knowledge (Omer and Goldblatt, 2007). It is important to note that the degree of complexity of a setting can vary depending on many factors. Bronzaft and Dobrow (1984) suggest that simplicity and regularity of the floor plan can assist people in learning about the layout of a setting. Weisman (1981) showed that the participants of his study reported being lost less often in the university buildings that they judged to be simpler. He also found that the most disorientation happened in buildings that were judged to be complex and that were difficult for people to describe. Similarly, O'Neill (1991a) found out that when a setting becomes more complex, then difficulties arise in understanding the layout. It has been argued that spatial comprehension and navigation are easier in a setting where the configuration is close to ''good form'' or 'good gestalt' characterised by simplicity, symmetry, regularity, and continuity (Abu-Obeid, 1998, Weisman, 1981). Lynch (1960) and others (De Jonge, 1962, Tzamir, 1975) state that city block matrices are easier to understand. However, some studies indicated that the dominance of a grid configuration in a setting can be misleading (Evans et al., 1984a). Analysing the configurational comlexity of the setting is a difficult concept (Peponis et al. ,1990). Howevere, the use of Space Syntax has become one of the objective ways to analyse the complexity of the built environment. The conceptual and methodological framework of Space Syntax, which takes a region of urban or architectural spaces and represents its path networks as a mathematical graph, has also been applied to the understanding of the effects of

configurationl complexity on the development of spatial knowledge (Haq and Zimring, 2003). Also, O'Neill (1991b) proposed ‘interconnection density’, which is described as the average number of directional choices at each decision point within the setting, as a measure for complexity. In a series of studies, he showed that when the interconnection density of a setting increases, the setting becomes more complex. This also influenced the number and placement accuracy of environmental features reported in participants’ sketch maps. In another study, Slone et al. (2015) compared the navigation performance of young participants in two virtual environments with different levels of complexity and stated that when interconnection density increased (complexity), it affected people’s spatial knowledge of the setting and therefore, it affected people’s spatial ability for navigation.

The differentiation (distinctiveness) of a setting is the degree or extent to which different parts of the environment have a different layout such as size, colour, shape, etc. (Kaplan, 1973, Kaplan, 1976, Gärling et al., 1986, Passini et al., 2000). Weisman (1984) also pointed out that differentiation makes the city’s overall layout and its parts more memorable, so differentiated environments are likely to have higher environmental legibility. He suggested that ‘non-uniform’ environments tend to facilitate the extraction and comprehension of environmental information.

Visibility is another influential factor on peoples’ spatial knowledge of a setting. Visibility, as an overall factor for a setting, is the degree to which different parts of a setting could be visually accessible (e.g. the locations which people can see from their origins, from their destinations, as well as from various salient points along their journey to their destinations) (Peponis et al., 1990). These aspects can influence the overall spatial knowledge acquired and the ability to construct a cognitive spatial representation of a given environment (Montello, 2005). There is a great branch of works regarding urban visibility studies (Benedikt, 1979, Conroy, 2001, Teller, 2003, Fisher-Gewirtzman and Wagner, 2003, Natapov and Fisher-Gewirtzman, 2016, Morello and Ratti, 2009, Nijhuis, 2011). Benedikt introduced two concepts of isovisit and isovisit field to objectively measure visibility over physical environment. The concept of isovisit is defined as the field of view available from a specific point of view. In scientific studies, an isovist is referred to a horizontal slice through the field of view taken at eye height which is parallel to the ground. The concept of the isovistfield, which is derived from the notion of isovisit, characterises a collection of views accumulated at each point in an open space. Numerous indicators and analyses around isovists and isovist fields were proposed by Benedikt (1979), De Floriani et al. (1994), (Batty, 2001) and Turner

et al. (2001). In order to measure the qualitative experience of human perception to quantify the visual experience in the third dimension, Fisher-Gewirtzman and other researchers (Fisher-Gewirtzman, 1998; Fisher-Gewirtzman et al., 2000; 2003; 2005) proposed a more realistic model for the translation of Benedikt's isovist in space. First presented by Fisher-Gewirtzman (1998), and later developed as an automated model (Fisher-Gewirtzman and Wagner, 2003; Fisher-Gewirtzman et al, 2003; 2005; Morello and Ratti, 2009), the spatial openness index was defined as the volume of the part of a surrounding sphere which is visible from a given point of view. The spatial openness index measures the net volume of open space, which aims to describe the quality of both perception and comfort. These methods can be used to objectively analyse the physical environment from visibility point of view.

Table 3.3 summarises the effects of the spatial factors discussed above on spatial knowledge.

Table 3.3 summarises the effects of the spatial factors on spatial knowledge

		Factors		Effect on spatial knowledge	Description
Elemental Factors	**Landmarks**	Spatial position of Landmark	Proximity to the main circulation system	↑	The landmarks that are central to the main circulation system can be remembered better.
			Proximity to a major decision point	↑	The landmarks that are around the main decision points can be remembered better.
			Internal/external landmark	↑	Both internal landmarks and external landmarks can contribute to build a clear image of the place.
		Visibility of Landmark	Visibility to the landmarks	↑	Landmarks that are more visible in physical environment can be remembered better.
			Inter-Visibility between landmarks and other main elements	↑	Inter-visibility between landmarks can facilitate comprehension of place.
		Built Form of Landmark	Size	↑	There is a positive correlation between these landmark characteristics and the extent to which they can be remembered by people.
			Form uniqueness		
			Historical and cultural significance		
			Colour, material, and details		
			Maintenance quality		
			Contour		
			Signage		
			Ease of pedestrian access		
			Use intensity		
			Landscape and naturalness		
	Nodes	Configuration of Node	Number of legs (paths)	↓	When the number of paths increases at an intersection, the ambiguity degree increases as well and it becomes harder for people to make a clear image of that intersection.
			Grid/ non-Grid layout	↑ ↓	Generally the nodes with grid layout can be learned easier than nodes with non-grid layout.
		Spatial position of Node	Centrality to the circulation system	↑	The nodes that are central to the main circulation system can be better remembered.
		Visibility of Node	Visibility to the node/inter-visibility between nodes and other elements	↑	Nodes that are better visible in physical environment can be remembered better.
		Nodes with landmark(s)		↑	Placement of landmark(s) at a node. (e.g a historic buildings placed at the corner of an intersection) increases the image clarity of the node.

Elemental Factors	**Paths**	Configuration of Path	Grid/ non-Grid layout	↑↓	Not specified.
			Length	↑↓	Not specified.
			Number of turns	↓	People better remember the paths that have a less number of turns along them
		Placement of landmarks along Path	Route with internal landmark	↑	Both internal and external landmarks can contribute to comprehension and learning the path, and the ease of navigation.
			Rout with external landmark	↑	
			No landmark	↓	
		Spatial position of Path	Integration	↑	The high integrated paths in the main circulation system can be better remembered.
			Connectivity	↑	The paths with great connectivity to the main circulation system can be better remembered.
Overall Factors		Complexity		↓	The degree of complexity of the physical environment is negatively correlated with spatial knowledge acquisition. The more complex the environments, the harder to comprehend and navigate the place.
		Distinctiveness		↑	The great level of distinctiveness within the setting tends to facilitate the extraction and comprehension of the setting.
		Visibility		↑	The degree of visual access within a setting is positively correlated with spatial knowledge acquisition.
Upward Effect: ↑ Downward Effect: ↓ Upward/ Downward Effect ↑↓					

3.5. Conclusions

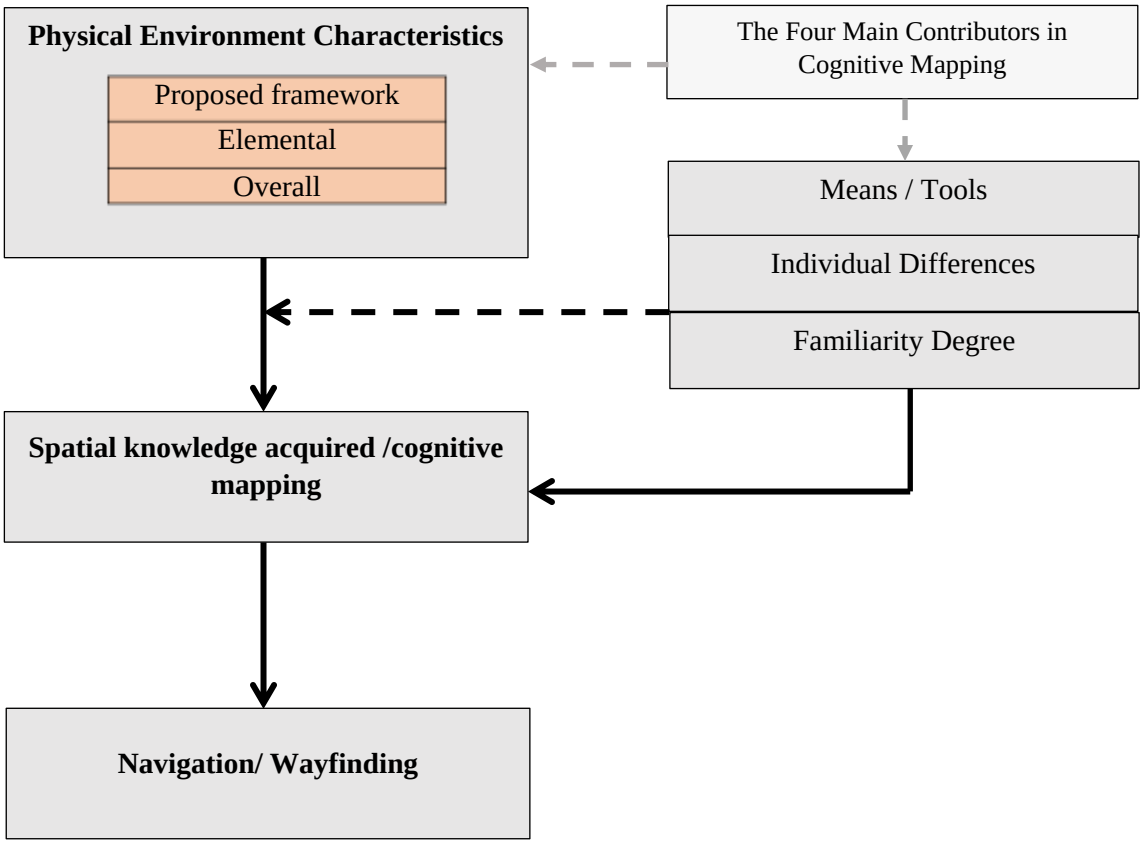
The emerging view of spatial cognition is that information processing in real-world contexts cannot be understood unless researchers can maintain enough conceptualisation of the physical domain in which people's spatial knowledge form and navigation occur (Evans et al., 1984b). Confirming this, both Wohlwill (1976) and Kaplan and Kaplan (1982) highlight the need to examine how the physical environment affects people's spatial knowledge. Indeed, spatial designers need to know the effects of physical environments on people's spatial knowledge. This can then enable them to design environments which can support people's cognitions and there is therefore a need for a systematic evaluation approach, whereby spatial designers can evalaute the physical environment and their design outputs.

This thesis proposes a framework which synthesises the spatial factors affecting spatial knowledge acquisition across the literature. This framework can be used as an evaluation framework for assessing the physical environments in relation to spatial knowledge acquisition and the extent of which the elements of the environment and their organisation can affect people's cognitive mapping. The main two sub-categories of the framework are elemental, and overall characteristics. The elemental characteristics is concerned with all spatial factors related to the elements of the physical environment, namely, landmarks, paths, and nodes, as well as the relation between them. However, the overall characteristics is concerned with overall features of the physical environment. These spatial factors, which are supported by their original empirical studies, are central to this evaluation framework. As researchers studying a complex built environment tend to merely focus on specific factors rather than studying all the factors, this paper therefore advocates that researchers take the interdependence of each spatial factor into account, but also suggests that they consider the potential trade-offs between factors. Also, considering these spatial factors in spatial design is not merely a checklist for the design process, rather, it is a necessary skill of design, which any designer should develop along with their other design/plan-making skills.

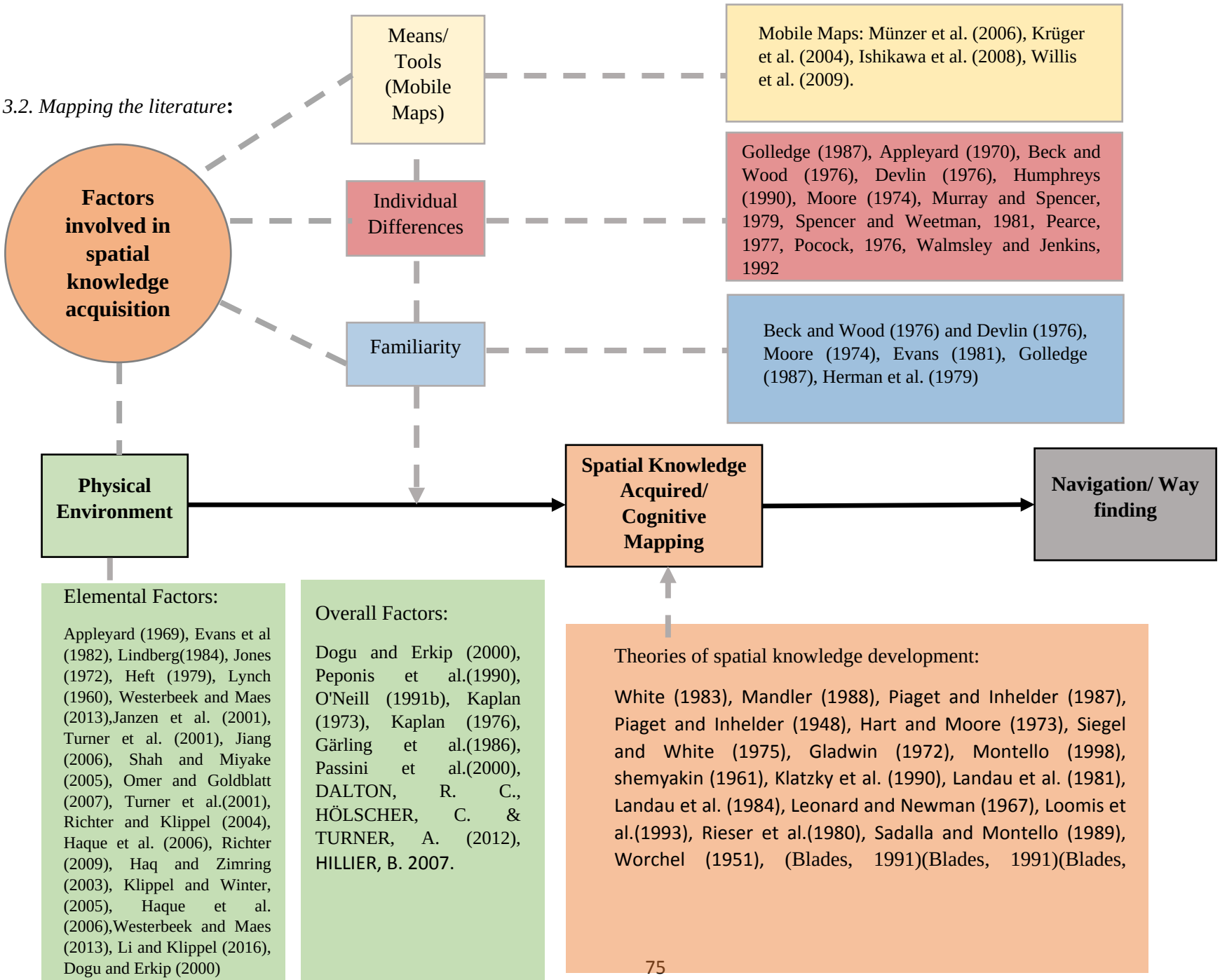
This thesis will further focus on the elemental factors presented in this framework. It will examine the association between the participants 'spatial knowledge acquisition and these elemental factors. Figure 3.1 illustrates the place of the proposed framework in the schematic diagram from previous chapter, which represented the relationships between physical environment, spatial cognition, personal experiences, and spatial behaviour (navigation). This also shows the place of the proposed framework in literature as well.

As this chapter is the end of part 1 (Research background and underpinning theories) of this thesis, figure 3.2 provides a map of literature and research background here. Figure 3.3 also highlights the factors that this thesis will specifically examine according to the aims of the thesis, which are: 1) the effects of mobile maps on spatial knowledge acquisition of people who use these systems for navigation, and 2) the effects of physical environment (elemental factors) on spatial knowledge acquisition of people who use mobile maps for navigation.

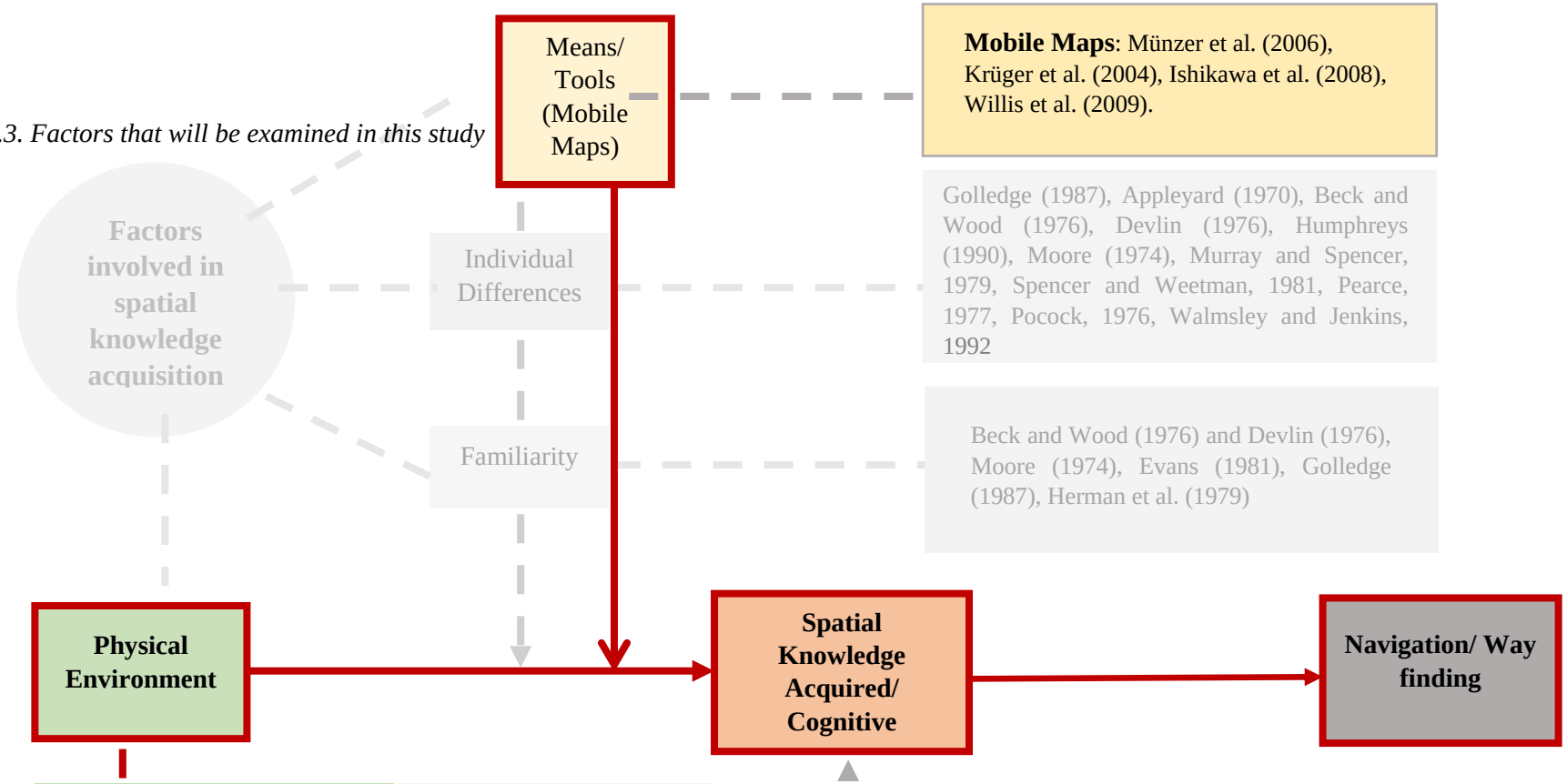
Figure. 3.1. Placement of the proposed framework in the schematic diagram from chapter two (figure 2.3), which represented the relationships between physical environment, spatial cognition, personal experiences, and spatial behaviour (navigation).

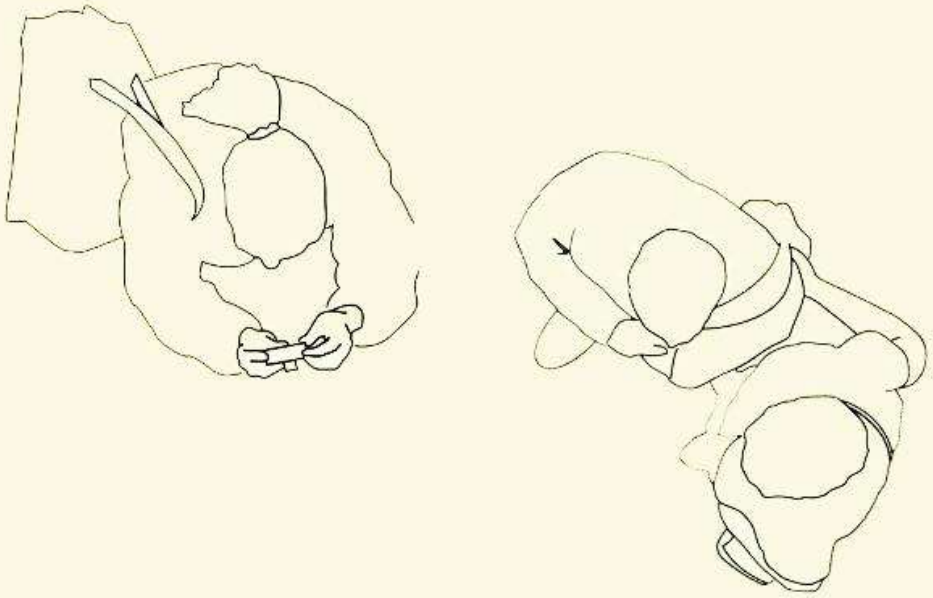


3.2. Mapping the literature:

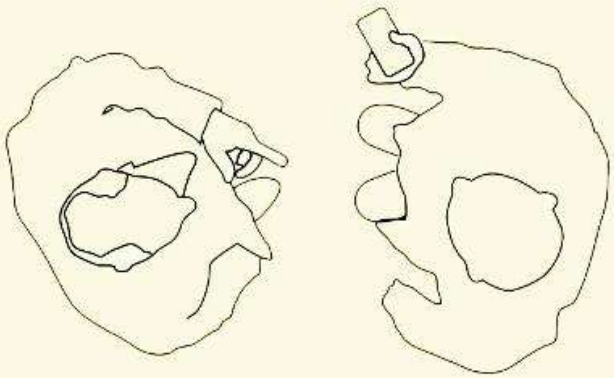


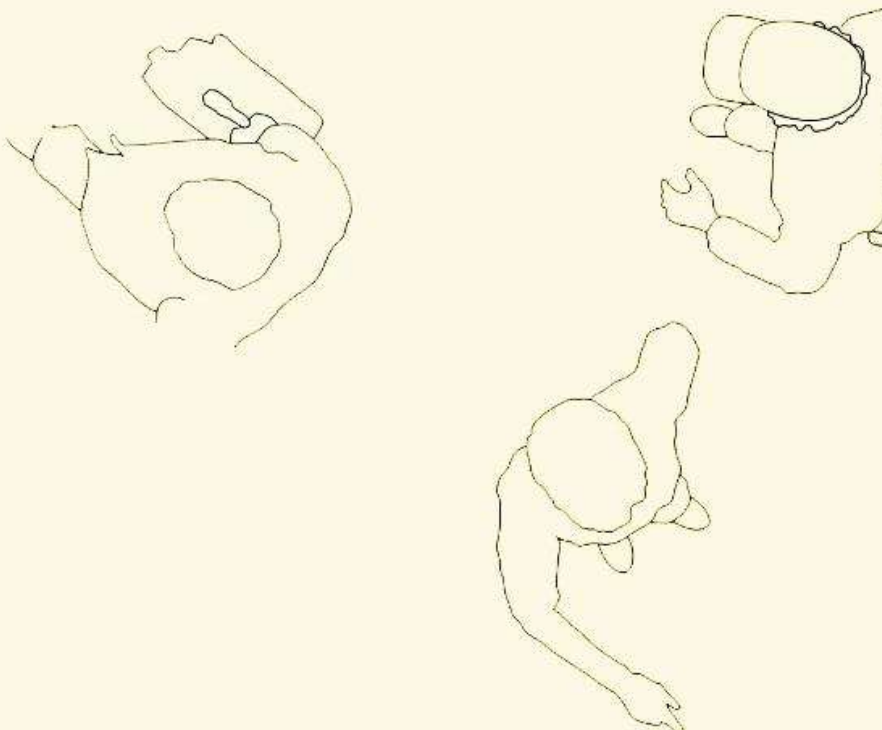
3.3. Factors that will be examined in this study





4. Conceptual Framework of the Thesis





The aims of this study are twofold: 1) to study the effects of Mobile Map (MM) Systems on people's spatial knowledge acquisition, and 2) to investigate the role of physical environment on spatial knowledge acquisition of people who use Mobile Maps for navigation. With studying this, we are able to understand firstly how people construct the urban environment in their cognitive maps while using mobile maps and secondly the role of physical environment and its spatial factors in this process.

The conceptual framework for this study is based on the following three arguments: first, the urban environment consists of physical elements (discrete elements) and topological relationships of these elements, which are understood by humans as cognitive representations in their minds; second, overall features of the city/neighbourhood structure or spatial configuration, and features of the discrete elements of the environment, namely, landmarks, paths, and nodes inherently affects humans' spatial cognition; third, the means or tools that people use for navigation, such as Mobile Maps, affect their spatial cognition.

4.1. The Conceptual model used in this study

Literature has shown that the physical environment is a determinant in forming people's spatial knowledge/cognitive maps. As discussed in the previous chapter, the discrete elements of the environment play an important role in people's spatial knowledge forming. Literature has shown that landmarks, nodes, and paths with specific features can contribute more effectively in forming people's spatial knowledge. These elements with specific features can be learned easier by people and move from individuals' temporary memory to their long term memory.

Why the focus of the study is on these three discrete elements, landmarks, nodes, paths? There are five discrete elements that commonly appear in cognitive maps: landmarks, paths, nodes, edges, and districts. Among these elements, landmarks, paths, and nodes are important. As it was indicated in table 2.1, edges are less important as physical elements that appear in cognitive maps. Edges are linear elements, such as, rivers, railroads, and walls, which are used as barriers, and do not let people easily move within them. As a result, they are less experienced, are less recalled by people, and are less represented in the cognitive maps. Regarding districts, they are middle-scale areas within the city which encompass the other elements (landmarks, paths, and nodes). They can be a neighbourhood or community. Their spatial features are overall and are described as overall factors in the previous chapter.

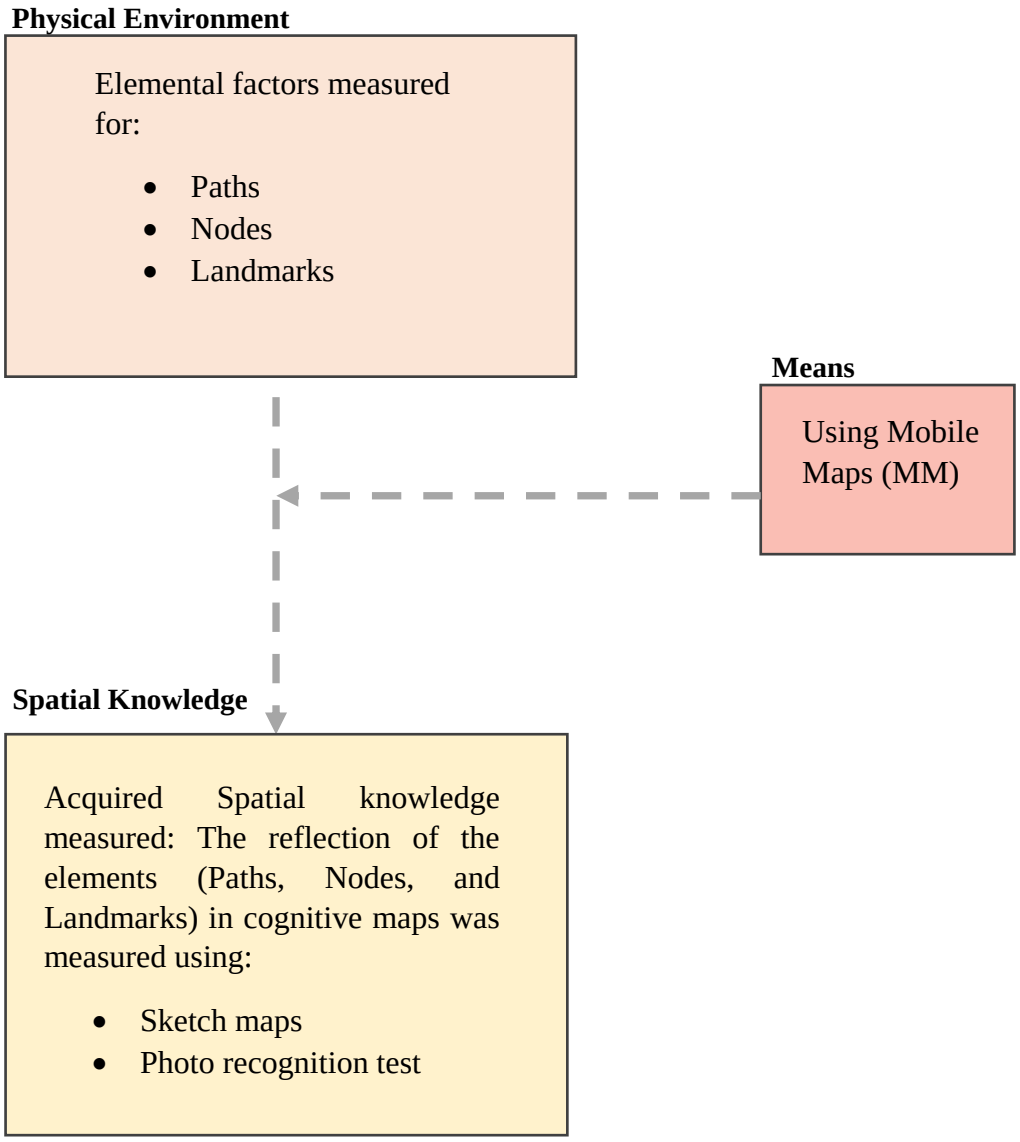
So, this study only focuses on the discrete elements of the physical environment: landmarks, paths, and nodes.

These elements with specific features are expected to be often reflected in people's acquired spatial knowledge / cognitive maps of the environment. Therefore, people's spatial knowledge of the environment should be studied in order to find out to what extent these elements are reflected in their acquired spatial knowledge of the site. This can be tested in different ways, two of which are sketch maps and photo recognition test. These methods will be discussed in methodology chapter in details. The features which are tested for the paths are as follow: length, number of turns, having internal and external landmarks. The features which are studied for nodes are: the number of legs, placement of landmarks at the node. The features which are examined for landmarks are: size, shape, signage, maintenance quality, texture, style, contour, colour/texture, visibility from roads, symbolic significance, use intensity, naturalness, siting characteristics, uniqueness of function, and type of nearby road. These features are adopted from the elemental factors from the proposed framework in chapter 3 (see table 3.2)

As it was discussed in the literature, the means/tools used for navigation also affect people's spatial knowledge acquisition. According to the literature, people using GPS based systems for navigation gain less accurate spatial knowledge from the environment. So the mean/tool of navigation (direct experience and mobile map in this study) will be considered as a moderating variable in this study.

Therefore, a conceptual model (figure 4.1) is developed firstly to study the effects of mobile maps on spatial knowledge acquisition of mobile map users, and secondly to investigate the relationship between the spatial knowledge acquisitions with mobile maps and the elemental features of the physical environment in real world; the extent to which the elemental features affect the acquired spatial knowledge through using mobile maps will be studied.

Figure 4.1: A conceptual model is developed to study the effects of mobile maps on spatial knowledge acquisition of mobile map users as well as the relationship between the spatial knowledge acquisitions by mobile maps and the elemental features of the physical environment in real world



4.2. Research questions:

The first set of research questions focuses on the quality and accuracy of spatial knowledge acquisition of people who used Mobile Maps for navigation.

Research question1: How is the acquired spatial knowledge by people who use Mobile Maps for navigation in comparison to acquired spatial knowledge by people who use other means of navigation (direct experience of the environment)?

- Sub-question 1-A: How different is the reflection of landmarks in people's spatial knowledge/cognitive maps between people who use mobile maps for navigation to those who experience the environment directly?

- Sub- question 1-B: How different is the reflection of paths in people's spatial knowledge/cognitive maps between people who use mobile map for navigation to those who experience the environment directly?

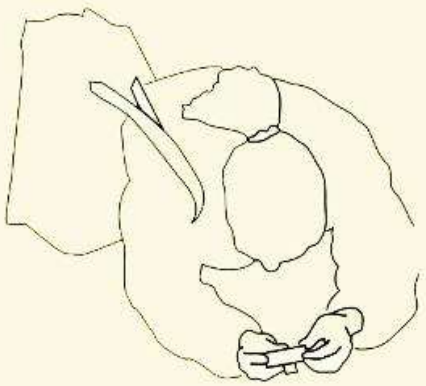
- Sub- question 1-C: How different is the reflection of nodes in people's spatial knowledge/cognitive maps between people who use mobile map for navigation to those who experience the environment directly?

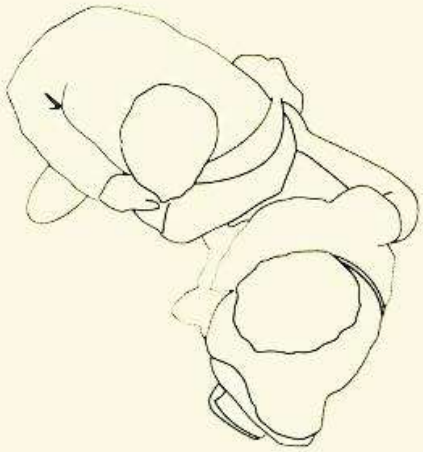
Research question 2: How is the effect of the physical environment on spatial knowledge acquisition of people who use mobile maps for navigation?

- Sub- question 2-A: How are the relationships between different spatial features of the landmarks in real world and the reflection of those elements in spatial knowledge/cognitive maps for both mobile maps users and direct experience users?

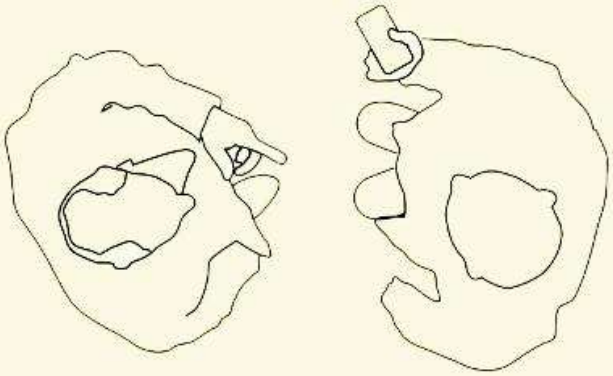
- Sub- question 2-B: How are the relationships between different spatial features of the paths in real world and their reflection in spatial knowledge/cognitive maps for both mobile maps users and direct experience users?

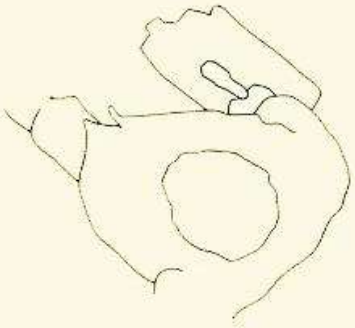
- Sub- question 2-C: How are the relationships between different spatial features of the nodes in real world and their reflection in spatial knowledge/cognitive maps for both mobile maps users and direct experience users?

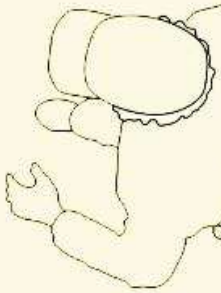


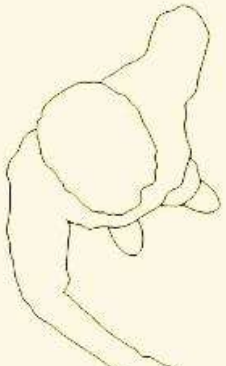


5. Methodology









5.1. Introduction:

The main objective of this chapter is presenting the research design through discussing the methodological approaches and methods that are undertaken in this study. For this purpose, in each stage of the research, different approaches are introduced and the selected research methods are discussed. This chapter not only discusses why these approaches and methods are selected, also explains what their limitations are. It is generally believed that the "right" methodology is the one that will answer the research question of the study (Holloway and Todres, 2003). This research employs a *field experimental and correlational* approach in which a series of psychological methods are used to investigate the effect of using mobile map (MM) users on people's spatial knowledge acquisition as well as the effects of physical environment on spatial knowledge acquired through using MM. The chapter begins with a discussion of the ontological, epistemological, and methodological positions of the research. The methods of data collection and data analysis are described, along with a discussion on why these methods are chosen, it also introduce the study area of the research.

Moreover, the next chapters, that particularly demonstrate the results of the study, will again briefly discuss the relevant methodological approach and methods that are used in the research.

5.2. Ontological, Epistemological and Methodological Position of the research

Ontological and epistemological positions that researcher adopts for the study can be a guide on choosing the methodological approaches and research methods for the study. Grix (2002) pointed out that it is important to have a clear statement of the ontological and epistemological assumptions of the research which enables the researcher to understand the basis of different approaches. Having such understanding helps the researcher to identify the position of their methodological approach among other methodological approaches available and also to completely understand the direction of the key components of the research process. Ontology is concerned with the nature of reality, however, epistemology is the relationship between the researcher and the known (Denzin and Lincoln, 2005). Blaikie (2009) explains ontological standing of a research as the "claims and assumptions that are made about the nature of social reality, claims about what exists. Ontological assumptions are concerned with what we believe constitutes social reality." On the other hand, he describes that the potential ways of acquiring knowledge of social reality and "claims about how what is assumed to exist can be known" are the epistemological stances. In other words, an

ontological position answers the question ‘what’s out there to know?’ and epistemological position answers the question ‘what and how can we know about it?’ (Grix, 2002). As Denzin and Lincoln (2005) mentioned, the ontological and epistemological positions of the researcher can define the research methodology or the way know the world and gain knowledge of it. In other words, by selecting their ontological and epistemological positions, researchers can know a ‘spot on the ‘methodological spiral and practice and experience their beliefs during the process of inquiry’ (Mills et al., 2006).

Several dichotomies or binary classifications are suggested for different research traditions, including, inter alia, scientific and hermeneutic (Marsh and Stoker, 2010), subjectivist or objectivist (Rubinstein, 2013), positivist and interpretivist (Denscombe, 2002). Nevertheless, two perspectives of objectivism and constructivism in ontology, and positivism and interpretivism in epistemology are usually taken into account as the major positions and traditions in the philosophy of social sciences. This study reflects an objectivism ontological perspective and a positivism epistemological position. Regarding the notion of objectivism, an objective reality exists and can be increasingly known through the accumulation of more complete information. Objectivism is a perspective adopted by certain practitioners in all the social sciences. In the field of environmental psychology, which would be used to illustrate the principles, objectivist ontology means that psychological phenomena, such as emotions, perceptions, reasoning, intelligence, memory, motivation, personality, developmental processes, are “real and have definite properties and causes” (Jonassen, 1991). This study which is concerned with spatial knowledge acquisition can be considered as an environmental psychology study with an objective ontological stance. Regarding the positivism, this approach does not allow for the subjective opinions of the researcher as the approach deals with verifiable observations and measurable relations between those observations, not with speculation and conjecture ” (Bryman, 2012). Therefore, this research takes a positivism epistemological approach. However, it is necessary to note that, as Grix (2010) points out, researches also might be ‘on the border’ between different ontological and epistemological positions, and it might be relatively impossible to locate them in one side of the various dichotomies.

Regarding methodological approach, it is believed that there are two distinct traditions or cultures in the research methodology; qualitative and quantitative. Their different ontological and epistemological positions and assumptions are usually considered as their basic distinction. In other words, qualitative and quantitative methodologists pursue different

research objectives that in turn lead to different positions and norms about conducting a research (Mahoney and Goertz, 2006, Bryman, 2006). Qualitative approach rejects positivist vision of replicating the success of the natural sciences to grasp the true reality in social phenomena. Qualitative researchers argue that social sciences have seen oversimplified by positivists. Many researchers define qualitative research based on its differences with quantitative research, whereas some other authors do not emphasize on this paradigm war. According to Bryman (2006), dichotomy of qualitative and quantitative research have been replaced by a "period of paradigm peace". Thus, definition of qualitative research should be adapted to this new era. According to Nkwi et al. (2001), "Qualitative research involves any research that uses data that do not indicate ordinal values." Although this definition is short and simple, it appears to be more practical. This definition avoids unnecessary generalisations and constraints on qualitative research. Furthermore, it is more compatible with so-called "paradigm peace" (Bryman, 2006), and avoids inaccurate dichotomous conceptualising of qualitative approach regarding to its quantitative counterpart. Quantitative approach quantify the problem/issue through producing numerical data or data that can be transformed into statistics. It is used to quantify attitudes, opinions, behaviours, and other defined variables – and generalize results from a larger sample population (Dervin, 1992). Quantitative Research employs measurable data to articulate facts and uncover patterns in research. And their data collection methods are much more structured than qualitative data collection methods.

According to objectivism ontological and positivism epistemological positions of this study, a quantitative approach is conducted in this research. As a methodology, the research work to conduct this thesis will employ a quantitative methodological approach that allows the use of accurate source of data.

Based on what researchers think that they can research on (ontological position) and what/how they can know about it (epistemological position), they can be able to choose their methodological approach. Nevertheless, research methods should be selected based on research questions and free from these assumptions (Grix, 2002). Methodology should not be confused with the research methods. According to Blaikie (2009), research methods are the "techniques or procedures used to collate and analyse data." Researchers usually use different sources of data and data collection methods without considering their qualitative or quantitative approach. For example, LeCompte and Schensul (1999) used survey, a classic quantitative method, in ethnographic qualitative research. Contrarily, narrative stories, which are associated with qualitative approach, are used by Elliott (2005) for quantitative event

history modelling. Moreover, in some researches, qualitative researchers might need to use quantitative data or closed-ended information including census records, attendance records and so on. Therefore, the sources of the data and methods of data collection are not necessarily different in these two research traditions.

5.3. Research Design approach:

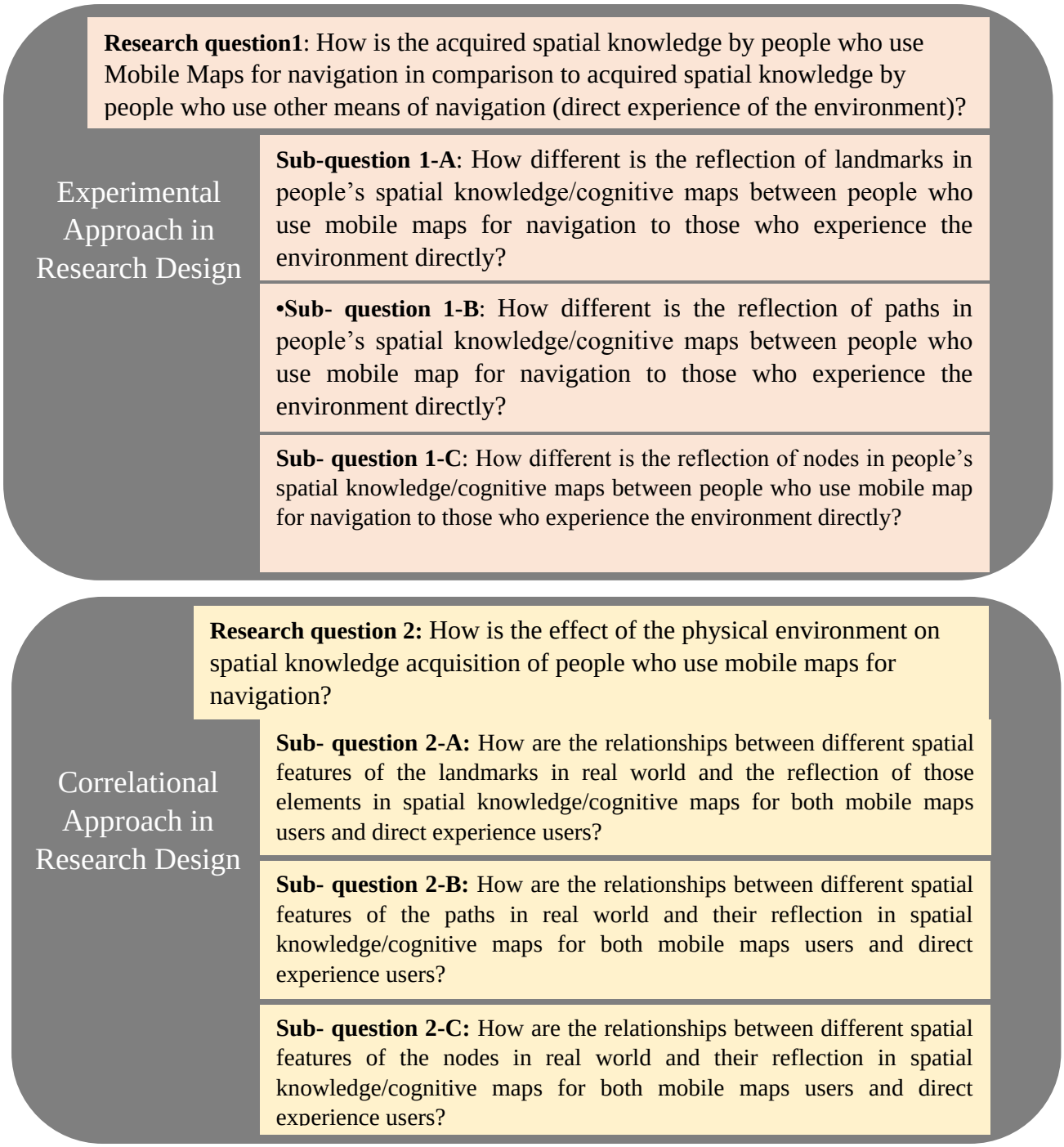
There are three main types of quantitative research designs and researcher should decide which research design is most appropriate for the research questions of the study. While there are many different investigations that can be done, a study with a quantitative approach generally can be described with the characteristics of one of the following three research design approaches: 1) Descriptive, 2) Correlational, 3) Experimental. These categories are described briefly in the table below (table 5.1):

Table 5.1 Research design approaches for quantitative research

Type	Definition
Descriptive	Descriptive research seeks to describe the current status of a phenomenon. In this approach, the researcher does not normally start with a hypothesis, but hypothesis can be likely developed after collecting data. Analysis and synthesis of the data provide the test of the hypothesis. Systematic collection of information requires careful selection of the units studied and measurement of each variable in order to demonstrate validity.
Correlational	Correlational research attempts to determine the extent of a relationship between two or more variables using statistical data. Relationships between and among a number of facts are sought and interpreted to recognize trends and patterns in data, but it does not go so far in its analysis to establish cause and effect for them. Data relationships, and distributions of variables are observed only. Variables are not manipulated; they are only identified and are studied as they occur in a natural setting. Sometimes correlational research is considered a type of descriptive research, and not as its own type of research, as no variables are manipulated in the study.
Experimental	Experimental research uses the scientific methods to establish the cause-effect relationship among the phenomena that make up a study.

This study using a quantitative methodological approach employs an experimental study to answer the first set of research questions of the study and a correlational approach to answer the second set of research questions of the study. The figure below (figure 5.1) demonstrates the research design approach chosen for the research questions of the study. The following sections then discuss the reasons to choose these approaches and their relevant data collection details.

Figure 5.1. The research design approach chosen for the research questions of the study



5.3.1. Experimental approach

In an experimental approach, the experiment(s) are designed in order to collect the data for answering the research question(s). The key points in experimental studies are controlling the *variables*[1], setting up carful measurements, and stablishing cause and effect relationships between *independent variables and dependent variables*[2]. In an experiment, a hypothesis is carefully tested and an independent variable (the cause) is manipulated to measure the effects of such changes on the dependent variable (effect); any other unimportant variable is controlled (Chin et al., 2000). The advantage of this approach is that the experiments are objective and, as a result, the views and opinions of the researcher do not affect the results of the study; this helps with increasing the validity of data collected and having less biased data (Harrison and List, 2004). The experimental studies fall into three types: 1) laboratory / controlled experiments, 2) field experiments, and 3) natural experiments. This study employs a field experiment to answer its first set of research questions.

Field experimentation is indeed the conjunction of two methodological approach, experimental study and fieldwork, in which the experimentation is carried out in an environment (such as a physical or virtual building, and urban area). Experimentation is a type of study that randomly assign units of observation (e.g. individuals, groups, institutions, states) to treatment and control groups. In assigning the observations to the treatment group, there will be a random procedure to ensure that each observation has the same probability to be allocated to the treatment group. Having random assignment can ensure that, in advance of receiving treatment, the experimental groups will have the same expected outcomes, which is an essential requirement for an unbiased conclusion. Experimental studies are moving away from observational studies, in which researchers come to conclusion through investigation the naturally occurring variation, as opposite to variation generated through random assignment (Goodin et al., 2011).

In a field experimental study, the experiment(s) are designed to be tested in the everyday environment of people. So the experimenter manipulates the independent variable to study the dependent variables, but the extraneous variables are not easy to control in an everyday

[1] A variable is any factor, trait, or condition in different types that can be influential in an experiment.
[2] The two fundamental variables in an experiment are the independent and dependent variable. An independent variable is the one that can be changed or controlled in a scientific experiment to test the effects on the dependent variable. A dependent variable is the variable that is tested and measured in a scientific experiment. When the experimenter make changes to the independent variable, the effect on the dependent variable is observed and recorded.

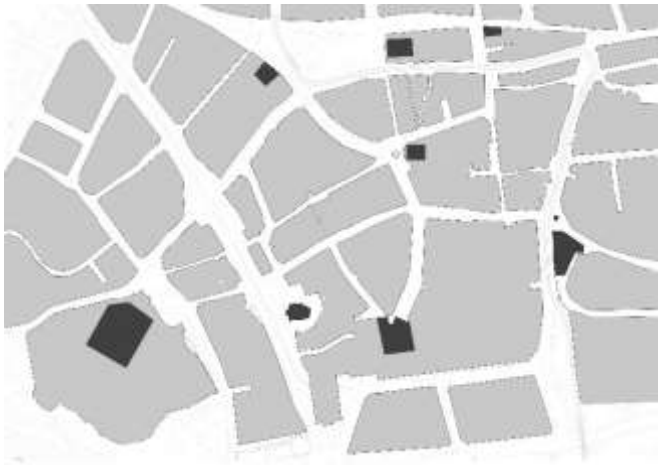
environment, such as an urban area. The advantages and disadvantages of this method are as follow: what is happening in a field experiment is more likely to reflect real life because of its natural setting, i.e. higher ecological validity than a lab experiment. Also, if participants do not know that they are being studied, there will be less likelihood of demand characteristics affecting the results. However, in experimental studies, there is less control over extraneous variables that might bias the results. This makes it difficult for another researcher to replicate the study in exactly the same way.

The field experiment is a suitable approach to answer the first set of research questions of the current study, as it aims to study a cause and effect relationship between the use of Mobile Maps (independent variable) and people's spatial knowledge acquisition (dependent variable) in an urban environment area. The field experiment has been used widely as a methodological approach for environmental psychology, and environmental and design studies, e.g. see (Saelens et al., 2003, Snellen et al., 2002, Ahern et al., 2014, Ewing et al., 2006, Felson and Pickett, 2005, Ishikawa et al., 2008, Ishikawa and Montello, 2006, Ittelson, 1976, Kahl et al., 1984, Klippel and Winter, 2005, Li, 2006, Meilinger et al., 2013, Montello, 2005, Rovine and Weisman, 1995, Westerbeek and Maes, 2013).

5.3.1.1 Environmental setting

This environmental setting chosen for carrying out the experiments of this research was a 14 Hectare of the city centre of Nottingham which is a medium-sized city in the centre of England with a greater urban population of around 730,000. The study area includes both modern and historic architecture with over 350 buildings and it retains a medieval historic pattern with 18 streets and 18 key street junctions. For the purpose of the experiment, a series of eight landmarks were identified within the site with each landmark being a building that was located on a single street (see Figure 5.2).

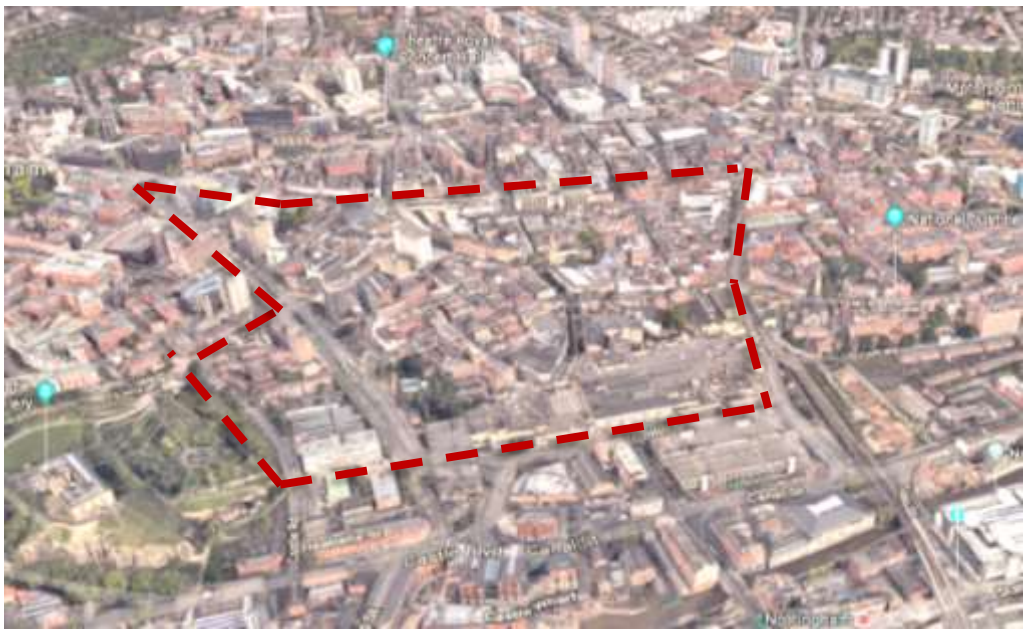
Figure 5.2: The map of the study site (indicating the eight landmarks used in the experiment)



Why this site?

Nottingham city centre was chosen as the study site for this research since this site met all the criteria that were necessary for the experiments. These criteria for selecting the sit were as follow: a) English town centre, b) consisting of both curve and perpendicular paths, c) including paths with different lengths, d) including both modern and old buildings, and e) including distinctive landmarks. The boundaries of the site were chosen considering to three points: a) the site should be big enough that includes the aforementioned criteria for the site, b) the area size should be walkable for the participants within the average time of 20 minute, c) the area should be defined by roads/paths that can help participants to understand both perceptual and physical boundaries of the site.

Figure 5.3: The 3D view of the site



5.3.1.2. Participants

In total, 76 participants, 38 female and 38 male, aged between18-28 (M= 22.86, SD=3.36 years) were selected for this study and were divided between two groups: Mobile Map (MM), and Direct Experience (DE). In order to minimise the effects of potential confounding variables (i.e. participant demographic features) and inter-participant variation and increase the observed differences across the independent groups (i.e. MM vs. DE), membership to the sampled was tightly controlled. This was managed in two steps: first by selecting the participants; and second by forming the groups. In selecting the participants, we used a 'purposefully-randomly strategy' (Sandelowski, 2000). The participants were randomly selected first year students attending at The University of Nottingham (September 2016) who met the following criteria: (a) they were British, born and bred in the UK. This increased the likelihood that they were familiar with the general culture of the neighbourhood; (b) none of the participants had any prior exposure to the study area; (c) they should have previously used mobile maps self-sufficiently in an urban area; (d) they were all right-handed. In order to group the participants, they were assigned to one of two groups (i.e. MM vs. DE) ensuring an even spread in demographic features across the independent variable.

Sample size

In addition to deciding how to select the samples for the quantitative components of a study, researchers also should determine appropriate sample sizes for each phase. The choice of sample size is as important as is the choice of sampling scheme because it also determines the extent to which the researcher can make statistical and/or analytic generalizations (Montgomery, 2008, Onwuegbuzie and Collins, 2007). The size of the sample should be informed primarily by the research objective, research question(s), and, subsequently, the research design. For achieving the purposes of this study, based on the similar research in this area, a sample group of 76 people are proposed to take part. The table below illustrates the similar research and the number of their participants. Moreover, Onwuegbuzie and Collins (2007) pointed out that for comparison study between two groups, 51 participants per group for one-tailed hypotheses; 64participants for two-tailed hypotheses. Also, for a correlational study 64 participants for one-tailed hypotheses; 82 participants for two-tailed hypotheses (Onwuegbuzie and Johnson, 2004).

Table 5.2 Research design approaches for quantitative research

Research	Number of participants	References
Wayfinding with a GPS-based mobile navigation system: A comparison with maps and direct experience	66- college students (11 men and 55 women)	(Ishikawa et al., 2008)
In-car GPS navigation: engagement with and disengagement from the environment	58- (45 men and 13 women)	(Leshed et al., 2008)
Spatial factors affecting wayfinding and orientation: A Case study in a shopping mall	154 –(76men and 78 women)	(Dogu and Erkip, 2000)
Wayfinding in an unfamiliar environment and different spatial settings of two polyclinics	114-(54 men-56 women)	(Baskaya et al., 2004)
Computer-assisted navigation and the acquisition of route and survey knowledge	64-(31 men- 33 women)	(Münzer et al., 2006)
Age effects on wayfinding and route learning skills	92- (36 men-56 women)	(Head and Isom, 2010)

According to the similar research, the number of participants is proposed to be 76 people, with equal number of men and women. This number of participants as the sample group of study could be promising to be large enough in order to pursuing the generalizability and validity aims of the research.

5.3.1.3. Self-report sense of direction test (SOD)

Participants were also tested for their self-report sense of direction (SOD); they filled out the Santa Barbara Sense-of- Direction Scale (Hegarty et al., 2002) . It consists of 15 statements to which participants express their degree of agreement on a 7-point Likert scale. Seven of the questions are stated positively (e.g., "I am very good at giving directions") and the other eight negatively (e.g., "I very easily get lost in a new city"). Participants answer the questions by giving 1 (strongly agree) to 7 (strongly disagree) to each question. The SOD test has largely been used as a measure of individual differences in spatial cognition, and the validity of this test has been demonstrated (Kozlowski and Bryant, 1977, Hegarty et al., 2002, Wen et al., 2011). For instance, Hegarty et al. (2002) showed that people who have a better SOD on this scale are good at updating their orientation and location in space as a result of self-motion. In our study, for each participant, the mean of their answers to the 15 sense-of-direction questions was calculated. Their answers were reserved to positively stated questions so that a higher score means a better sense of direction, ranging from 1 to 7. To ensure that evaluations of SOD given by participants across the two groups (MM and DE) were similar, statistical significance testing was performed and showed that there is no significant difference between two groups (Table 1).

Table 5.3.Results of t-test for comparing the mean of SOD between the two groups

MM M (SD)	DE M(SD)	ΔM	t	df	*p*-value	Cohen's d
4.71(0.46)	4.63 (0.49)	0.08	0.725	74	0.156 n.s.	0.17 small effect

***p≤0.001; **p≤0.01; *p≤0.05; n.s. =not significant (p>.05).

The study was approved by The University of Nottingham Research Ethics Committee for Human-based Research and all of the participants gave written informed consent. Participants were given Amazon vouchers in return for their participation.

5.4. Experiment design:

The participants from both groups, MM group and DE group, were exposed individually to the study area. Following a briefing, participants from both groups were asked to find the 8 destinations within the site, starting from the same start point. MM users were asked to find the destinations by using the GPS app and DE users were asked to find the same destinations by relying on physical features in the site and directional signs. The protocol for DE users

designed to mirror their natural behaviour when they are exposed to an unfamiliar environment without access to their mobile phones.

The location of the destinations within the site and the order that participants were asked to find them were structured in a way that meant that both MM users and DE users were likely to walk through the same routes in the same sequence. This was tested many times in the pilot study by manipulating the order of landmarks to make sure that both groups for moving from one destination to the next one would go through the same route (Figure 5.3 & 5.4). MM users were told to choose the shortest route that GPS offers and in the case of DE users, the efficiency of directional signs were examined; there were guiding signs located at each main decision point of the study area indicating the way to the landmarks chosen for the test. The challenge of the experiment was to design a protocol for participants in a way that both DE users and MM users would walk through the same routes. The configuration of routes and syntax of the 8 chosen landmarks in relation to the routes as well as the placement of the directional signs at the main decision points of the study site (in the case of non-GPS users) could bring an advantage to the design of the test. As a result, participants for both groups chose the same routes for approaching the destinations and passed by the same sequences as predicted.

In the entire journey, participants were followed by two experimenters, keeping a distance of about 50 metres. Consistent with the navigational experiment designed by Ishikawa et al. (2008), in some cases the participants were going away from the boundaries of the study area or were heading to a road that was not part of the study and after 10 minutes had passed, they were guided by the experimenter to the routes that were part of the study. After finishing this phase, in order to collect the data to answer the research questions, the participants were asked to draw a ‘sketch map’ to investigate their spatial knowledge of the study area, specifically, their knowledge of discrete elements of the setting, such as paths, nodes, and landmarks. Moreover, they were required to undertake a ‘photo recognition task’ in order to exclusively explore the level of their visual knowledge. Figure 5.5 illustrates some of the photos from the experiment procedure.

Figure 5.4. This map demonstrates landmarks (The order of finding landmarks is marked) and the study routes in the site

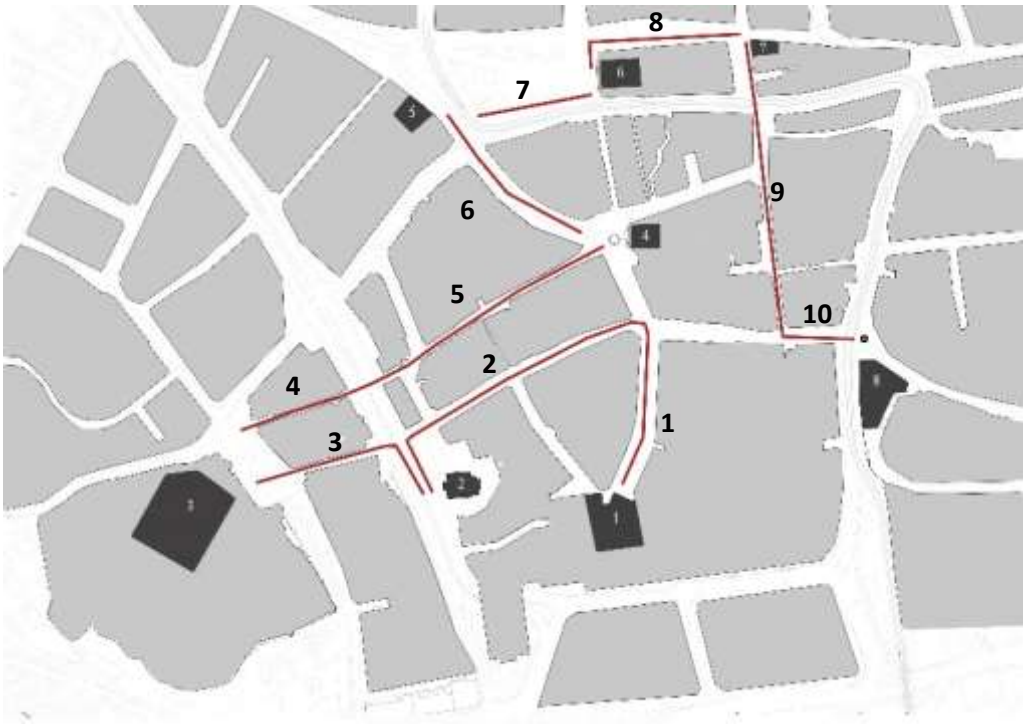


Figure 5.5. GPS map displayed for moving between destinations

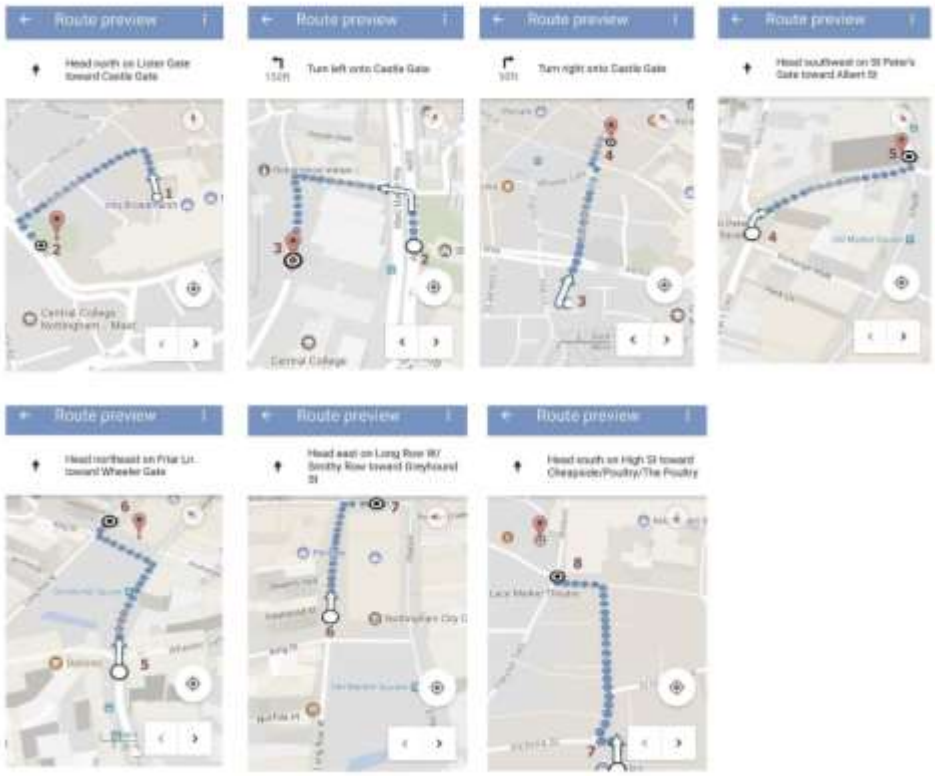


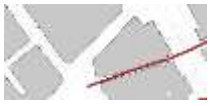
Figure 5.6. Illustrating the study paths

Path number from the 5.4

1

2

3



4

5

6

7

8

9

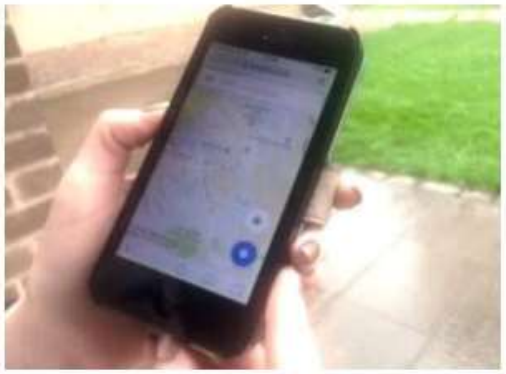
10

Figure 5.7. Illustrating the experiment procedure: (a) a non-GPS participant is using the directional signs to find the destinations; (b) a non-GPS user arriving at one of the destinations by paying close attention to landmarks; (c) and (d) the GPS participants using the GPS app to find the destinations.

(a)

(c)

(b)



(d)

5.4.1. Time of the study

The experiments all took place from the 27th September to the 18th October 2016. The time of the study was limited to weekday mornings in order to avoid busy times in the study area during afternoons and weekends. Also, participants' exposure to the site in terms of time needed to be similar, as the time of the day (e.g. the number of pedestrians in the street, etc.) could affect their navigation and perception of place.

5.5. Data collection methods

As part of the experiment, in order to collect the data regarding the participants' spatial knowledge of the environment they have been through, the sketch map drawing method and photo recognition test as two common methods for examining the acquired spatial knowledge were employed. These methods are discussed in the following sections.

5.5.1. Sketch map drawing

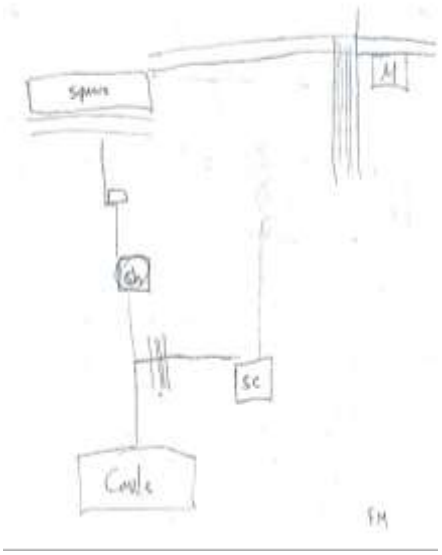
Sketch map drawing has been widely used to represent human' acquired spatial knowledge (Kim, 2001). It has long appeared to be a useful instrument for recovering information about the way people mentally represent the environment. In this study, after the participant's exposure to the site, they were taken to a sitting area near to the ending point and were required to draw a sketch map of the area that they have been through on an A4 sheet. They were structured to draw all the buildings, spaces, streets and details of the area as accurately as they could remember. There was no time limit for this task and they were encouraged to finish their drawings when they think it is completed. A sample of sketch maps developed by participants in the two groups is shown in figure 5.4.

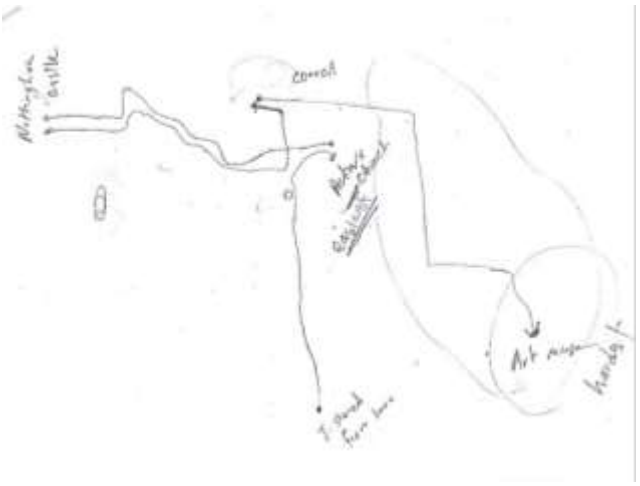
Golledge (1976) characterises four distinct methods for the 'extraction' of environmental cognition information: (1) experimenter observation of behaviour in naturalistic or controlled situations; (2) historical reconstructions; (3) indirect judgment tasks; and (4) analysis of descriptions, sketch maps, photo recognition, modelling, etc (Moore and Golledge, 1976). The notion of a cognitive map implies that the spatial actor possesses some kind of internal mental ordering of the external environment that people consult in the process of making movement decisions or responding to environmental stimuli. So sketch maps have been used in many environmental psychology research (i.e. Lynch, 1960; Wong, 1979; Kitchin, 1994) in order to elicit information about the people's mental representation of environment from the individual in terms of the characteristics and locational relationship of spatial forms, the

qualities attributed to environmental elements, as well as the preferences for and the evaluation of spatial opportunities.

The sketch map drawing method can be used to extract information on the way in which the spatial actor mentally structured the environment into a coherent picture. This kind of mapping exercise is more advantageous than verbal expressions if the system of interest is the locational relationships of spatial elements. However, there are also certain limitations that must be taken into consideration. Despite the instructions given, the sketch maps produced will certainly be affected by the 'mappability' of the environmental elements and by the ability of the respondent to express in cartographic form. Hence it is expected that differences will exist between different groups of people and between different places and cultures. It has also been pointed out (Pocock, 1976) that two other variables may also affect the validity and comparability of results: the physical complexity of the environment under study and the areal extent over which cognition is demanded. The greater the complexity and the areal scale, the more difficult it is for the respondents to draw a coherent picture of the environment. In the study area, these should not present any serious theoretical problem as the spatial extent of Nottingham city centre is quite small and the layout of the town is quite simple. Also, the individual differences, including gender, age, and the level of their sense of direction were tightly controlled ensuring an uneven sample grouping for this study.

Figure 5.8. *Mobile Map Participants*





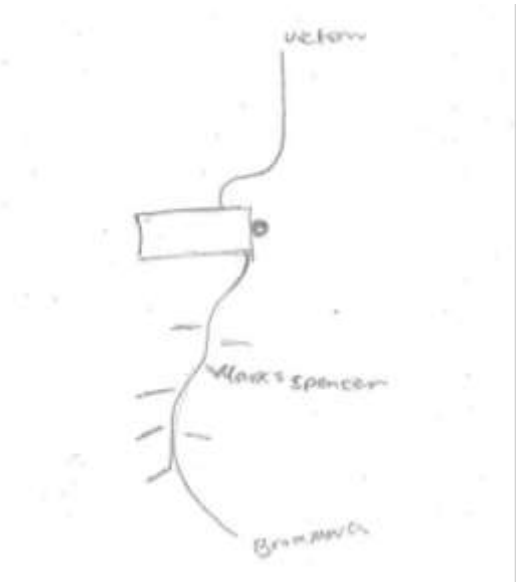
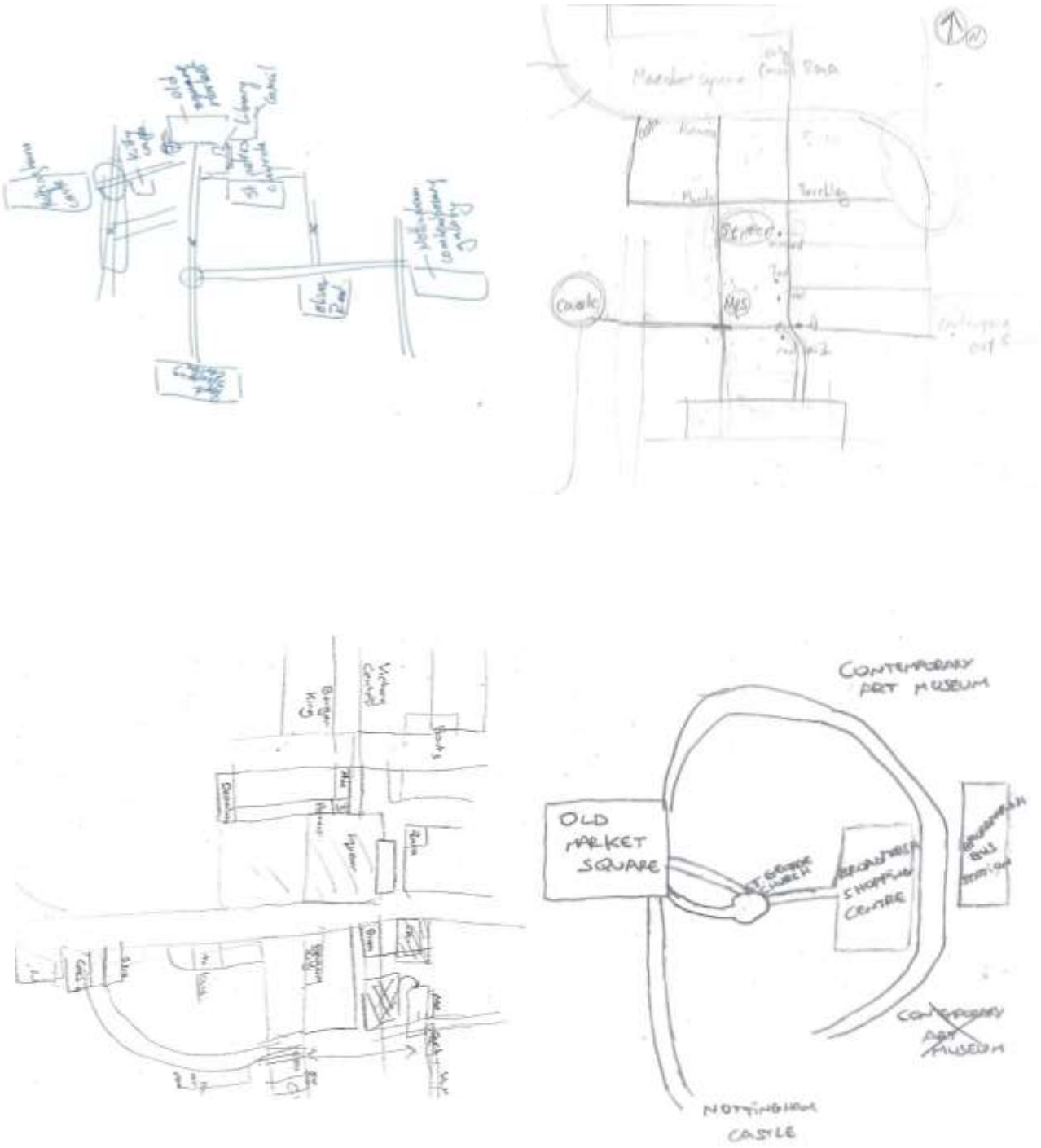


Figure 5.9. Direct Experience Participants



5.5.2. Photo recognition test

In order to examine visual knowledge amongst MM users and DE Participants, the photograph recall test was designed to assess the level of their recall and recognition of different buildings. In this test, photographs depicting 68 buildings within the case study site, from the routes that participants walked through, were presented to both groups of participants and they were required to indicate to what extent they could recall each building. For this question, they were asked to use a five-point Likert scale from 1 (definitely remember) to 5 (don't remember at all). The photographs were sized 210mm x 300mm and they were taken from a similar angle to that which each participant would see the building from in his/her journey through the site. Also, in this test, there was no time limit and participants were self-paced.

Similar photographic tests to assess people's recognition of a place have been previously used in several research projects, for example, see (Milgram, 1972, Weber et al., 1978, Hepner et al., 2007, Wen et al., 2011, Campbell et al., 2014). Indeed, Milgram (1972) and Weber et al. (1978) presented photographs taken from their study location to participants in order to determine whether they could recognise the scene depicted. Significantly, Weber et al. (1978) mention that although this method has a potential response bias, it is still strong method to analyse peoples' recognition of place. Campbell et al. (2014) use photographs as one method of measuring people's landmark recognition in Sydney as part of their project 'The Sydney City Test of Topographical Memory' where the test was designed to measure the level of building recognition within a defined case study area. In a navigation study, very similar to the experiment of this thesis, Wen et al. (2011) designed a 'scene recognition test' in order to assess their participants' landmark knowledge. In their study, 24 photos were shown to the participants and they were asked to indicate if the photos had been taken from the routes that participants learned from videos with verbal, visual and spatial interference tasks and without any interference.

5.6. Correlational study

In order to answer the second set of research questions, a correlational study approach was employed. This approach was used to determine the association between spatial features of paths, nodes, and landmarks and the acquired spatial knowledge from these elements.

In general, correlational study is a quantitative research methods which test two or more variables from the same group of participants against each other. This methods try to determine if there is any relationship between the two variables or not (statistically speaking, this is a similarity between their score patterns, not a difference between their means). The correlational methodological approach is used in this research in order to answer the second set of research questions of the study. It is attempted to find out if there is any relationship between the spatial features of paths, nodes, and landmarks in real world (the experimental setting of the study) and their accuracy of reflections in people's cognitive map or spatial knowledge acquired.

There are different quantitative correlational tests that can be used to examin the relationship between variables. Pearson Correlation Coefficient and discriminant analysis are used for this research, they will be discussed in details in Analysis chapters (next chapters- chapter 6 and 7).

5.7. Summary of methodology

According to the conceptual model of the study, research design and methodological approach discussed above, the overall scheme of the study concepts, indicators, measurements, and data analysis employed in this study are shown in the Table below (table 5.3).

Table 5.4. MATRIX OF CONCEPTS, INDICATORS, MEASURMENTS, AND DATA ANALYSIS

<table>
<tr><th>Concepts</th><th colspan="3">Indicators</th><th>Methods of Data Collection</th><th colspan="2">Measurements</th><th>Data Analysis</th></tr>
<tr><td rowspan="3">Spatial knowledge acquired by MM and DE</td><td rowspan="3">Cognitive Representation</td><td rowspan="3">Physical Elements</td><td>Paths</td><td>Sketch Map</td><td colspan="2">Measurement of Streets/paths in sketch maps: ordinal encoded</td><td rowspan="3">• Unit analysis of paths, nodes, & landmarks: Comparing the path scores, nodes score, and landmark scores using a series of t-tests
• Analysing the photo recognition test: Comparing landmark knowledge (buildings) using a series of Man-Whitney U Tests</td></tr>
<tr><td>Nodes</td><td>Sketch Map</td><td colspan="2">Measurement of Streets conjunctions/nodes in sketch maps: ordinal encoded</td></tr>
<tr><td>Landmarks</td><td>Sketch Map and photo recognition Test</td><td colspan="2">• Measurement of building in sketch maps: ordinal encoded
• Measurement of buildings in photo recognition test: ordinal encoded</td></tr>
<tr><td rowspan="4">Relationship between spatial knowledge acquired (by MMand DE) and physical environment</td><td colspan="3">• Gognitive Representation of Paths, Nodes, and Landmarks</td><td>Sketch Map and Photo Recognition Test</td><td colspan="2">• Measurement of Streets/paths, Nodes, and landmarks in sketch maps: ordinal encoded
• Measurement of buildings in photo recognition test: ordinal encoded</td><td rowspan="4">• Correlational analysis between the two indectors: correlation between path scores, node scores, and landmark scores and their spatial features measured from the physical setting
• Discriminant Analysis</td></tr>
<tr><td colspan="3" rowspan="3">• Physcial Elements of the Environment, Paths, Nodes, and Landmarks</td><td rowspan="3">• The raters' knowledge of the physical setting
• GIS</td><td>• Measurment of the spatial features of the paths: ordinal encoded</td><td>Length, number of turns, containg inter/external landmarks</td></tr>
<tr><td>• Measurment of the spatial features of the Nodes: ordinal encoded</td><td>Number of legs, containg landmarks</td></tr>
<tr><td>• Measurment of the spatial-physical features of the Landmarks: ordinal encoded</td><td>Visibility,Size, shape,maintenance quality, texture, style, contour, symbolic significance, use intensity, siting</td></tr>
</table>

5.8. Quality Considerations of The Study

5.8.1. Internal Validity

As Groat and Wang (2002) mentioned the fundamental issue of internal validity is whether the key concepts and operations of the study are truthful representations of the object of the study. Therefore, in order to make sure that the methods and measurements in this study are the true operations of the concepts, a pilot stydy was conducted in September 2015.

Another more important issue in internal validity is whether the differences in people's spatial knowledge between the two groups, MM and DE, could be attributed to the use of mobile map (independent variable). This goal was achieved by carefully selecting the sample groups, it was ensured that the effects of potential confounding variables (i.e. participant demographic features) and inter-participant variation are minimised, this was explained in details, above, in the participants section. Therefore, the differences between the two sample groups, MM and DE groups, were the least possible and the only main difference between them was the navigation mean (independent variable) which was using Mobile Map or not (Direct Experience).

5.8.2. Construct Validity

Construct validation focuses on assessing the validity of the measurements. The core of construct validity is whether the measurements actually measure what they should measure. As Carmines and Carmines and Zeller (1979) asserted, construct validation involves three distinctive steps: first, specifying theoretical relationships between concepts; secondly, examining relationships between measures of concepts; and thirdly, interpreting evidence in terms of how it clarifies the construct validity of particular measures.

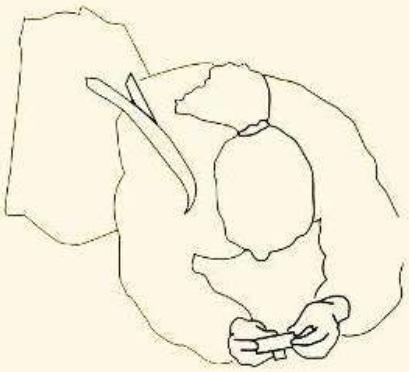
In this study tends to provide a great deal of literature review of previous studies on spatial cognition, spatial knowledge acquisition, wayfinding in order to create the conceptual model of the study. The proposed conceptual model clearly and accurately defines what would constitute human spatial knowledge acquisition, cognitive maps, cognitive representations, and includes a rationale for the correspondence from the concept definitions to methods and measurements as shown in figure 4.1 and Table 5.3.

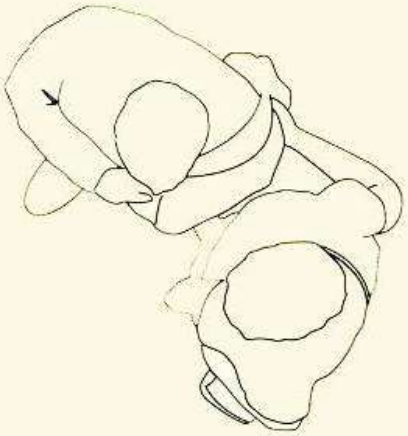
5.8.3. Reliability

The concept of reliability is concerned with the consistency of the measurements or findings. The assumption is that the research methods would yield the same results if the study was conducted under the same conditions at another location or time (Groat and Wang, 2002). In this study, the reliability of instruments is of most concern. To achieve this goal, first, most of the measurements/instruments adopted in this study have been used successfully in previous studies. Additionally, the pilot study was conducted before final data collection to make sure that the instruments could clearly and correctly work for this study. Second, since the reliability of scoring the sketch map and photo recognition test is a concern in this study, the previous studies on how to encode the sketch maps quantitatively were reviewed (Lynch, 1960; Cohen, 1980; Wiseman, 1981; Evans et al., 1984; Kim, 2001) and then a systematic encoding criterion for sketch maps was developed. In addition, two independent raters judged the sketch maps based on the developed encoding systems, they rated the spatial features of the environmental setting as well. Interrater reliability for sketch maps and objective physical features of landmarks, Nodes, and paths were calculated by using a Pearson product moment (Boyatzis, 1998). The interrater reliability for all of them were high, more details will be presented in analysis chapter (chater 6 and 7).

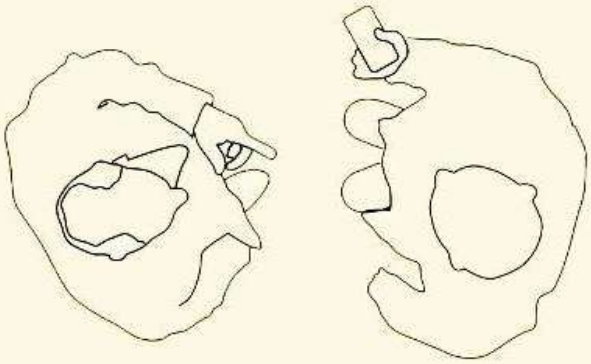
5.9. Limitations of the study

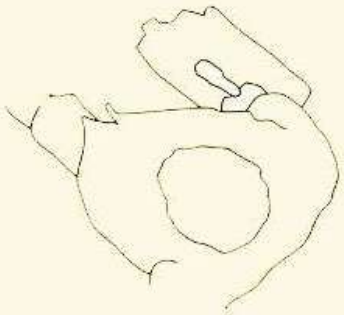
There are two key limitations to the research presented in this thesis. Admittedly, the arguments of the study are a consequence of our dependent measure of survey knowledge, which involved using sketch maps as well as testing landmark knowledge by using photo recognition test. In further research, other additional measures such as a pointing test, orientation test, and photo relocation in maps could have helped to further substantiate the difference between mobile maps users and direct experience users in acquiring spatial knowledge. Secondly, the study included only one study area that clearly limits the generalisability of the findings and therefore expanding the number of contexts within which the research is undertaken will provide more conclusive results.

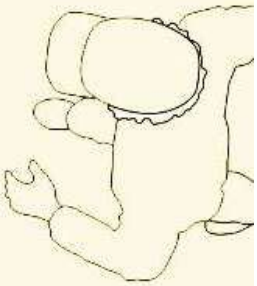


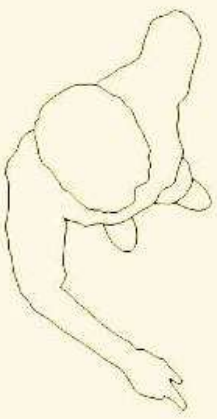


6. Analysis of the Sketch Maps, Results and Discussion









6.1. Introduction:

In spite of growing use of GPS-based systems for navigation, as discussed in previous chapters, there has been little evaluation of the effects of these systems on people's spatial knowledge acquisition (Devlin, 2017). On the other hand, in the few studies that analysed the effectiveness of these systems in acquiring spatial knowledge, the role of physical environment on spatial knowledge acquisition has received little attention. The aim of this thesis is to address these gaps. To this end, this chapter compares spatial knowledge acquisition of participants who used Mobile Map (MM) for navigating an unfamiliar urban environment to the participants who navigated the same environment without technological assistance, or in other words Direct Experience (DE). This is tested through using 'sketch map drawing', which was discussed in previous chapter (methodology chapter). This part, therefore, answers the first set of research questions of the study. Furthermore, this chapter questions how the physical-spatial features of the physical environment have influenced the spatial knowledge acquisition of mobile map users. In answering this question (second set of research questions of the thesis), the research focuses on the elements of physical environment, namely, paths, nodes, and landmarks. Then, the association between the physical-spatial features of these elements in the real world and the correctness of their depiction in the sketch maps drawn by MM and DE participants are examined.

6.2. Analysis of the sketch maps:

The sketch maps collected for this study were analysed in two phases; in the first phase, they were tested to determine the extent to which participants placed the configurational elements, such as paths, landmarks, and nodes correctly in the sketch maps across the two groups. The second phase of the analysis examined the association between the depiction correctness of these elements in the sketch maps and some of their spatial features in real world.

First phase:

First, a schema was developed in order to score the placement correctness of the elements (landmarks, paths, and nodes) in the sketch maps. To do so, consistent with the method used by (Long and Baran (2012)), a list was made of all the paths and nodes that the participants went through. For landmarks, a list of buildings included in all sketch maps, considered to represent all landmarks in the site, was developed. Then, using Long and Baran's (2012) methodology, paths were scored on a 4-point ordinal scale ranging from 0 to 3 and included the following path/street categories: street did not exist in the sketch map, incorrectly drawn (wrong location or direction), partly correctly drawn (distortions in curve, and/or angle,

and/or number of turns, and/or length), and correctly drawn. A similar scoring schema was developed for assessing the landmarks with a 4-point ordinal scale employed to score landmarks in each sketch map. The scale ranged from 0 to 3 and included the following categories: landmark not drawn on the sketch map, incorrectly located, partly correctly located (along the right path/street, but in a wrong location), and correctly drawn. Similarly, nodes were scored using a 4-point ordinal scale from 0 to 3 included the following categories: nodes did not exist in the sketch maps, incorrectly drawn (wrong location), partly correctly drawn (along a right path/street, but in a wrong location, and/or having wrong number of paths forming the node), and correctly drawn. Second, after scoring each participant's sketch map, a path score, landmark score, node score was calculated for each participant by summing up the scores for paths, landmarks, and nodes drawn by the participant. Third, a series of independent- samples 't tests' (two-tailed) were applied to compare the mean score obtained for each element across two groups (Table 6.1).

Table 6.1: Path Scores, Landmark Scores, and Node Scores for Mobile Map Group (MM) and Direct Experience Group (DE)

	MM		**DE**		**ΔM**	**t**	**df**	**p-value**	**Cohen's d**
	M (SD)	Range	M (SD)	Range					
Participant Path Score	6.75 (11.60)	0-18	16.80 (4.60)	2-40	9.13	-4.3	74	0***	0.95 large effect
Participant Node Score	5.90 (4.50)	0-18	12.15(7.45)	1-28	6.21	-4.40	74	0***	0.90 large effect
Participant Landmark Score	7.80(4.70)	0-22	16.80(11.45)	2-42	9.00	-4.50	74	0***	0.90 large effect

***p≤0.001; **p≤0.01; *p≤0.05; n.s.=not significant (p>.05).

As shown in table 6.1, there is a significant difference in the Participant's Path Score between the Mobile Map Group and Direct Experience Group (M MM=7.15, SD=5.20, and M DE=15, SD=10.30, P<0.001). This indicates that those who used mobile maps tended to draw

the paths less correctly than those who navigated the site through direct experience. Similarly, comparing the Participant Node score between the Mobile Map Group and the Direct Experience Group, it was clear that the participants who did not use a mobile map were significantly more likely to draw the nodes more correctly (M MM=7.15, SD=5.20, and M DE=15, SD=10.30, P<0.001). The analysis also revealed similar results for landmarks, whereby participants who did not use mobile maps for navigation placed the landmark in the sketch maps more often correctly compared to those who used mobile maps (M MM=7.15, SD=5.20, and M DE=15, SD=10.30, P<0.001).

Second phase:

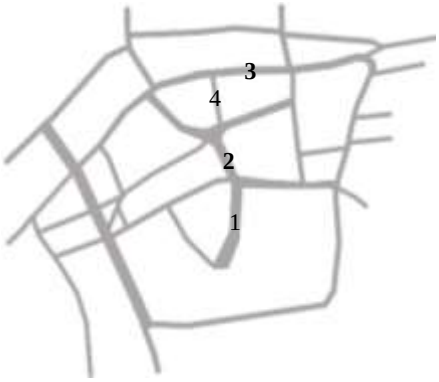
In this phase, the association between the topological correctness of drawing the elements of the study site in the sketch maps by two groups and the physical spatial features of those elements in real world was tested. In order to do that, first, using the scoring schema developed in the first phase, the mean score for each single street/node/landmark, from the list in the first phase, was calculated. This mean score shows the degree to which a specific street/node/landmark was correctly drawn by the participants. According to the schema scale, the mean can range between 0-3, and a higher mean score, therefore, shows that specific street/node/landmark is correctly depicted more frequently in the sketch maps by participants. Second, once the mean score for each street/node/landmark has been calculated then this can be analysed in order to find out if there is any association between the mean score of these elements in the sketch maps and their spatial features in real world. The analysis for paths, nodes, and landmarks are elaborated in the following sections.

6.2.1. Paths:

The mean score was calculated for each single street/path as well as the frequency of which the streets were placed correctly in the sketch maps (had score 3); Table 6.2 and figure 6.1 show the paths/streets which had a higher mean score, meaning, those paths were represented correctly in the sketch maps by more participants.

Table 6.2 & *Figure 6.1: Streets with the highest mean score and the frequency of their correct appearance*

	Street Name	MM			DE		
		M Score	Frequency of correctly placed (total number=36)		M Score	Frequency of correctly placed (total number=36)	
			N	%		N	%
1	Lister Gate	2.10	20	52.60%	2.70	25	65.70%
2	Albert St	2.20	22	58.00%	2.80	27	71.00%
3	Cheapside	2.10	19	50.00%	2.60	24	63.10%
4	Exchange St	1.60	16	42.10%	2.50	23	60.50%



This result indicate that both groups gained more accurate spatial knowledge from the four streets illustrated in table 6.2, as they were more frequently depicted correctly in the sketch maps. For example, the mean score for Lister Gate Street is 2.10, and 2.70 in MM and DE respectively. This street also appeared 20 times correctly (had score 3) in 38 sketch maps (52.60%) by the MM group and 25 times (65.70%) in 38 sketch maps by the DE group.

Number of Turns and Length

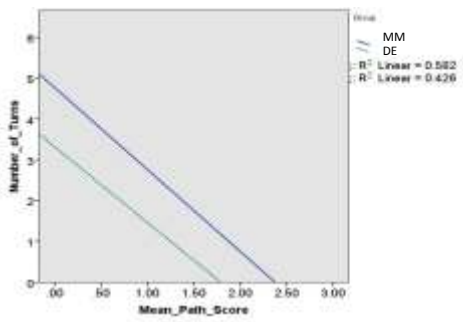
This chapter then examined the possible association between street scores, which show the extent to which a street is drawn correctly in the sketch maps, with the number of turns along a street and its actual length.

Table 6.3: Correlation analysis

	Number of Turns		Length	
	r	p-value	r	p-value
MM	-.76**	0	.21	.3
DE	-.65**	0.01	-.10	.85

Correlation is significant at the 0.01 level (2-tailed).

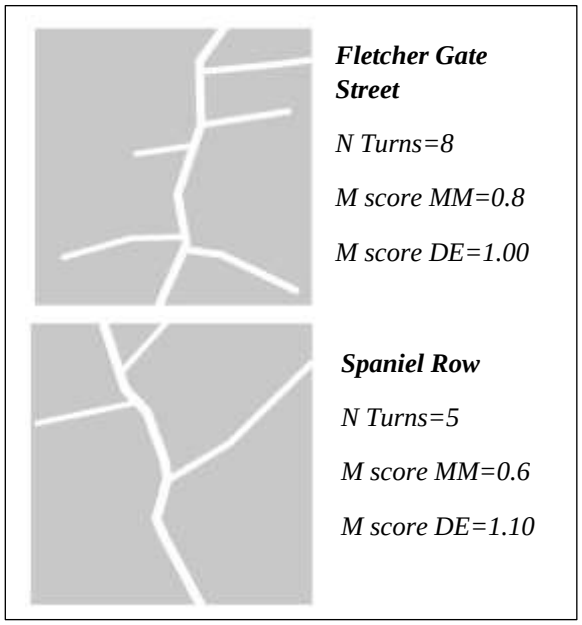
Figure 6.2: correlation between Street Mean Score of paths and Number of Turns



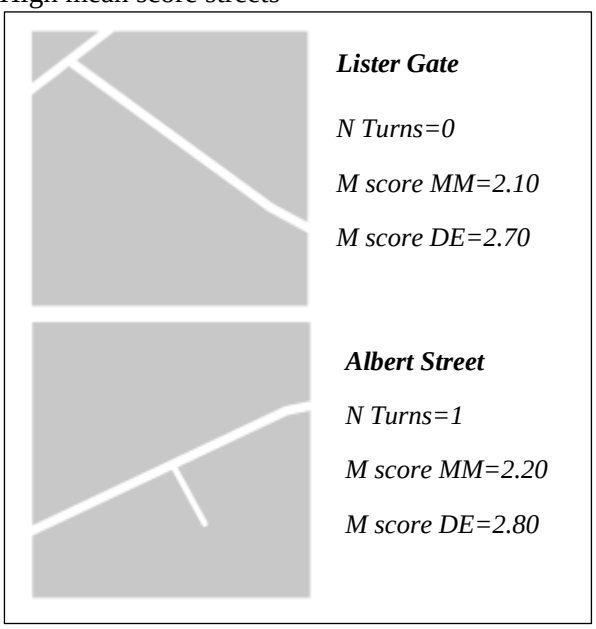
The result (table 6.3, and figure 6.2) suggests that there is a negative correlation between the number of turns along a street and the placement correctness in the sketch map for both groups. This correlation is stronger for mobile map users, however, both groups of participants, those who used mobile maps for navigation and those who navigated the environment non-aided technology, struggled to acquire accurate spatial knowledge from the streets, which have more turns. Significantly, however, mobile map users acquired even less accurate spatial knowledge from such streets. This suggests that the number of turns along a street can be a good indicator for acquiring spatial knowledge for both mobile map users and non-mobile map users. Regarding the length, the geographic information systems (GIS) was used to objectively measure the actual length of the streets for this analysis. Then, the correlation analysis between length and mean score was tested, however, the analysis did not show any correlation between placement correctness of streets in sketch maps and the actual length of the street. The figure below (6.3) illustrates the configuration for some of the paths (indicating the path with number of turns along them) with a high mean score versus a low mean score.

Figure 6.3 illustrates the configuration for some of the paths with a high mean score versus a low mean score.

Low mean score streets



High mean score streets



The chapter also examined whether a path/street containing internal landmarks or external landmarks can have any influence on the depiction correctness of the path in the sketch maps or not, in other words, if the streets with internal landmarks have higher mean score or not in any of the groups. To do so, two urban planners, 'blind' to the purpose of the study, ranked the paths if they have internal landmarks or not, and if they have external landmarks or not. The researcher then conducted t-test analysis to compare the mean score for streets that had internal landmarks to those that did not have internal landmarks (table 6.4). A t-test was used to find out if there was a significant difference between the means scores of the streets with external landmarks to those without external landmarks (table 6.5).

Table 6.4: t test analysis to compare the mean score of the streets with internal land marks to those without internal landmarks

	With internal landmark	Without internal landmark	ΔM	t	df	p-value
	M (SD)	M (SD)				
DE M Score	2.00(0.6)	1.20 (0.35)	0.80	-3.00	18	0.007**
MM M score	1.20 (0.55)	0.75(0.35)	0.45	-1.90	18	0.07 n.s

***p≤0.001; **p≤0.01; *p≤0.05; n.s. =not significant (p>.05).

Table 6.5: t test analysis to compare the mean score of the streets with external land marks to those without external landmarks

	With external landmark	Without external landmark	ΔM	t	df	p-value
	M (SD)	M (SD)				
DE M Score	1.80 (0.70)	1.70 (0.55)	0.10	-0.25	18	0.13 n.s
MM M score	1.20 (0.70)	1.00(0.50)	0.20	-0.60	18	0.23 n.s

The analysis (Table 6.4) shows that the streets that had internal landmarks have a significantly greater mean score compare to those that did not have internal landmarks for DE participants. This indicates that streets with internal landmarks can be better remembered

topologically by direct experience participants and they are therefore more likely to be drawn correctly in the sketch maps. However, according to the analysis, having an internal landmark along a path did not show to have any significant effect on depiction correctness of paths by MM participants. Moreover, with regards to the analysis in this study, the streets with external landmarks did not show any significant difference in mean score to the streets without external landmarks, or in other words, having an external landmark did not seem to have any significant influence on topological remembrance of the paths (Table 6.5).

Complex paths with internal landmarks

Although analysis showed that paths with more number of turns and intersections along them are depicted correctly less often in the sketch maps, it was also evident that paths with internal landmarks are drawn more accurately. This hypothesis was tested using a t-test for the paths with more than 3 turns ($3\leq n$) and referred to as complex paths in the analysis. These complex paths were organised into two categories: (a) complex paths with internal landmarks, and (b) complex paths without internal landmarks (Table 6.6).

Table 6.6: t test analysis to compare the mean score of the Complex Paths with landmarks to Complex Paths without landmarks

	Complex Path with internal landmark	Complex Path without internal landmark	ΔM	t	df	p-value
	M (SD)	M (SD)				
DE M Score	2.00(0.34)	1.00 (0.10)	1.00	-5.20	8	0.001***
MM M score	1.10 (0.30)	0.65(0.40)	0.45	-1.80	8	1.00 n.s.

***p≤0.001; **p≤0.01; *p≤0.05; n.s. =not significant (p>.05).

The result of the t-test demonstrated that complex paths with internal landmarks were correctly depicted more often by DE users, however existing internal landmarks along the complex paths did not have a significant effect on the correctness of the MM participants' path drawing.

6.2.2. Nodes:

The mean score was calculated for every single node from the list, table 6.7 and figure 6.4 illustrate the nodes that had the highest mean scores. Nodes with a higher mean score were those that appeared correctly more often in the sketch maps. Also, the frequency of which the nodes were placed correctly in the sketch maps (had score 3) was calculated.

Table 6.7 & Figure 6.4: Nodes with the highest mean score and the frequency of their correct appearance

		MM			DE		
	Node Name	M Score	Frequency of correctly placed (total number=36)		M Score	Frequency of correctly placed (total number=36)	
			N	%		N	%
1	Node 2	1.80	15	41.50%	2.00	20	52.60%
2	Node 3	1.95	16	44.50%	2.20	22	58.00%
5	Node 8	2.00	21	58.30%	2.50	25	69.00%
6	Node 13	1.90	14	39.00%	2.30	22	58.00%
7	Node 14	2.00	20	52.60%	2.25	23	60.50%
8	Node 15	2.00	20	52.60%	2.30	23	60.50%

Number of node legs

The association between the numbers of node legs (i.e. number of streets entering a junction) in real world and depiction correctness of nodes in sketch maps was also analysed.

Table 6.8. Correlation analysis

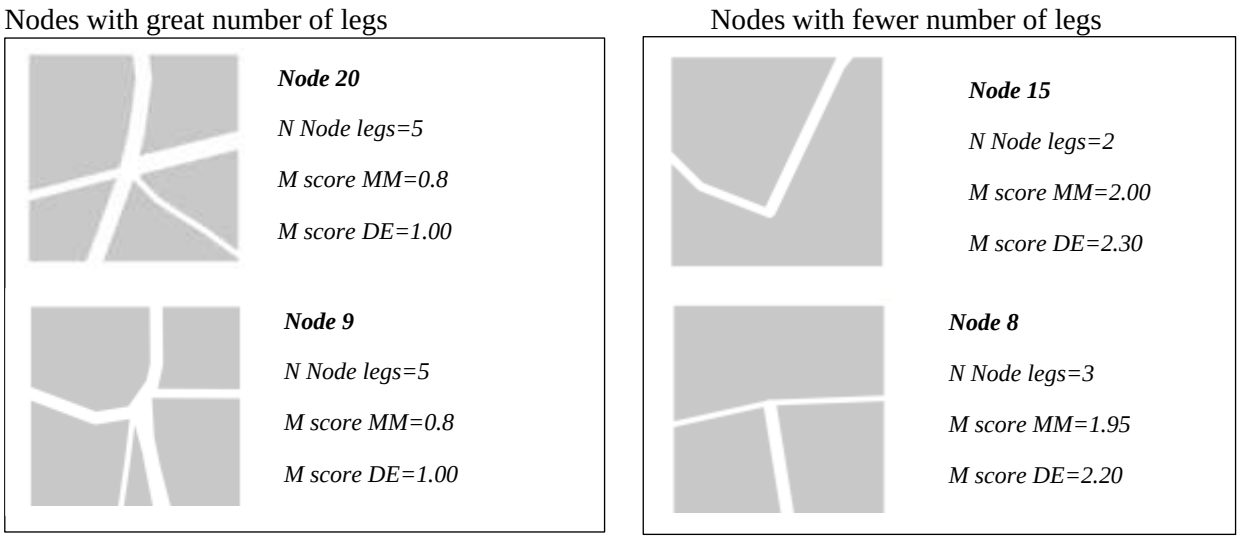
	Number of Legs	
	r	p-value
MM	-.62**	0.004
DE	-.50*	0.01

**Correlation is significant at the 0.01 level (2-tailed). * Correlation is significant at the 0.05 level (2-tailed).

The analysis (Table 6.8) demonstrates that there is a negative correlation between the number of node legs in real world and depiction correctness of nodes in sketch maps for both groups, but this correlation was stronger for mobile map participants. This shows that when the

number of node legs increases, it becomes more difficult to comprehend the nodes correctly for both the MM and DE groups, however, as this correlation is stronger for MM users, it is likely to be even more difficult for them. The figure (figure 6.5) below highlights examples of nodes with many versus a few legs and indicate their relevant mean scores; the nodes with more legs have a low mean score and nodes with fewer number of legs have a high mean score.

Figure 6.5. Examples of nodes with many versus a few legs and indication of their relevant mean scores



Containing Node-landmark

The potential influence of containing landmarks at the corner of nodes (i.e. node-landmark) on the depiction correctness of nodes in sketch maps was also tested; the mean score of nodes containing landmarks compared to the mean score of the nodes without landmarks using a t-test (table 6.9).

Table 3.9. t- test analysis to compare the mean score of the Nodes with node-landmarks to those without nodes-landmarks

	Nodes with node-landmark	Nodes without node- landmark	ΔM	t	df	p-value	Cohen's d
	M (SD)	M (SD)					
MM M Score	1.65(1.30)	1.00(0.90)	0.65	-2.65	18	0.02 *	Medium Effect
DE M score	2.00(0.40)	1.25 (0.60)	0.75	-2.90	18	0.008**	Large effect

***p≤0.001; **p≤0.01; *p≤0.05; n.s. =not significant (p>.05).

This analysis showed that nodes containing landmarks are likely to be correctly depicted more often in the sketch maps for both groups.

Complex nodes with landmarks and without landmarks

The analysis in above sections reveals that nodes with more node-legs tend to have a lower mean score and are depicted less correctly in the sketch maps. It is also evident, however, that the nodes with more legs that contain a node-landmark have a higher mean score and are drawn correctly more often than other nodes with a similar number of legs. Therefore, it was tested whether the existence of a landmark at a node with a large number of legs can help participants to comprehend that node better and depict that node more correctly in sketch maps. This was tested for complex nodes with more than four legs using a t-test to compare their mean score (table 6.10). These complex nodes were divided into two groups: a) complex nodes with landmarks; and b) complex nodes without landmarks.

Table 6.10. t test analysis to compare the mean score of the Complex Nodes with landmarks to Complex Nodes without landmarks

	Complex Nodes with a landmark	Complex Nodes without a landmark	ΔM	t	df	p-value	Cohen's d
	M (SD)	M (SD)					
MM M Score	1.20(1.40)	0.50(0.80)	0.70	-1.80	10	0.05	Medium Effect
DE M score	1.90 (0.50)	0.90 (0.70)	1.00	-2.80	10	0.01	Large effect

***p≤0.001; **p≤0.01; *p≤0.05; n.s. =not significant (p>.05).

Analysis of these tests illustrated that the mean score for complex nodes with landmarks are significantly higher than complex nodes without landmarks in both groups. This suggests that placing landmarks at the corners of the nodes with more number of legs (i.e. complex nodes) can increase their legibility for both groups.

6.2.3. Landmarks:

The mean score for every single landmark from the first phase was also calculated. Table 6.11 shows that the landmarks that had highest mean score as well as the frequency of their correct appearance (score of 3) in the sketch maps.

Table 6.11: Landmarks which had the highest mean score and the frequency of their correct appearance (score of 3) in the sketch map

	Node Name	MM			DE		
		M Score	Frequency of correctly placed (total number=36)		M Score	Frequency of correctly placed (total number=36)	
			N	%		N	%
1	Landmark1	1.60	12	41.50%	2.10	19	52.60%
2	Landmark3	1.95	14	44.50%	2.60	21	58.00%
3	Landmark5	2.10	19	58.30%	2.80	25	69.00%
4	Landmark10	2.60	21	39.00%	2.80	22	58.00%

Visibility

It was also important to test if the visibility to the landmarks can have any influence on the extent to which landmarks are placed correctly in the sketch maps. To evaluate the visibility for each landmark, the scale used by Appleyard (1969) was adopted but adapted to suit this research study. As such, two urban planning professionals who were unaware of the details of the research study were asked to rate the visibility of each building listed in phase one. The visibility of the these landmarks were rated according to three attributes: a) immediacy - the landmark's measure of distance and centrality to the line of view; b) proximity to the main decision points - the landmark's presence at important decision points and points of transitions; and c) significance of viewpoint - an estimate of the number of people who might see the landmark regularly from its most commonly used viewpoint. The landmarks were then rated from low to high on a three point Likert scale. The correlation between the rates of a landmark's attributes and the its mean score from the sketch maps were then computed (table 6.12).

Table 6.12: Correlation analysis

		Immediacy		**Proximity to the main decision point**		**significance of viewpoint**	
Landmarks Mean Score		r	p-value	r	p-value	r	p-value
	MM	0.36	0.08 n.s.	0.45*	0.02	.37	.07 n.s.
	DE	0.65**	0.001**	0.65**	0.001	.67**	0.000

** Correlation is significant at the 0.01 level (2-tailed) - *Correlation is significant at the 0.05 level (2-tailed).

Analysis of the results shows a medium, positive correlation between the immediacy of a landmark and its mean score for DE group, which was statically significant (r=0.65, N=23, p=0.001). However, the analysis did not show any correlation between the immediacy of a landmark and its mean score. This shows that when the immediacy of a landmark increases, it is more likely that the DE users will draw that landmark more correctly in sketch maps, but it does not have a significant effect on the MM users' maps. Similarly, there was a medium, positive correlation between the significance of the viewpoint to a landmark and its mean score for the DE group, which was statically significant (r=0.67, N=23, p=0.000). There was, however, no correlation between these two factors for the MM users. This demonstrates that landmarks that are placed where the significance of their viewpoint is higher (i.e. where more people pass by), those landmarks are more likely to be depicted correctly in sketch maps by DE participants. However, this factor does not affect the depiction correctness of landmarks in sketch maps for the MM participants. Furthermore, a positive correlation was also found between the proximity to the main decision points and the landmarks' mean scores in both MM and DE groups. This correlation was small for the MM group and medium for the DE group. The static significance of the correlation for the DE group and the MM group are respectively as follows: (r=0.65, N=23, p=0.001); and (r=0.45, N=23, p=0.02). This showed that the landmarks that are closer to the main decision point are likely to be drawn more correctly by both the DE and the MM participants.

6.3. Summary of analysis

The table below (table 6.13) summaries the sketch map analysis and indicates the influence of the factors (analysed above) on depiction correctness of paths, nodes, and landmarks in the sketch maps.

Table 6.13: Summary of Analysis

Elements	Factors	The influence of factors on depiction correctness of elements in the sketch maps		Description
		MM	DE	
Paths	Number of Turns	✓	✓	When the number of turns along a path increases, the mental representation of path becomes poorer
	Length	×	×	Length of the path did not show any significant influence on the mental representation of path
	Containing internal landmarks	×	✓	The paths with internal landmarks were drawn correctly more often than the paths without internal landmarks only for DE, not MM
	Containing external landmarks	×	×	The paths with external landmarks did not show to have a significant influence on depiction correctness of the paths for both DE and MM
Nodes	Number of Node-Legs	✓	✓	When the number of node-legs increases at a node, the nodes are more likely to be depicted correctly less often in the sketch maps by both DE and MM
	Containing landmarks	✓	✓	Nodes with landmarks are more likely to be depicted correctly more often in the sketch maps than the nodes without landmarks, by both DE and MM
Landmarks	Immediacy	×	✓	The landmarks that are placed at the vision line of travellers are depicted correctly more often in the sketch maps by DE, but it did not have a significant effect on MM
	Proximity to the decision points	✓	✓	The landmarks that are placed close to the decision points are more likely to be depicted correctly in the sketch maps by both DE and MM
	Significant of viewpoint	×	✓	The landmarks which were at the main paths are likely to be depicted correctly more often in the sketch map by DE, but not by MM

6.4. Discussion

Sketch maps which test the mental representation of physical environment used as a method to compare spatial knowledge acquisition of participants who used Mobile Maps (MM) for navigating the site to spatial knowledge acquisition of Direct Experience participants (DE). The analysis showed that the sketch maps drawn by MM users were significantly more distorted than DE's sketch maps. Paths, nodes, and landmarks were depicted significantly less often correctly in the sketch maps by MM than DE (table 6.1). Similarly, Ishikawa et al. (2008), who compared Mobile Map users, Physical Map users, and Direct experience participants in spatial knowledge acquisition in an urban environment also reported that Mobile Map users drew sketch maps with poorer topological accuracy than the other two groups.

Moreover, studies have shown that the spatial features of the components, namely, paths, nodes, and landmarks make difference in spatial knowledge acquisition and including them in the sketch maps (Appleyard, 1969, Evans et al., 1984b, Rovine and Weisman, 1989). However, investigating the influence of such spatial features on spatial knowledge acquisition of people using Mobile Maps for navigation has received little attention. This study identified several spatial features that are likely to be influential on mobile map users' spatial knowledge acquisition in comparison to direct experience users. We tested the extent of depiction correctness of paths, nodes, and landmarks from the study site in the sketch maps against some of their spatial features in real world for both DE and MM groups.

Paths:

Based on the analysis of this study, the number of turns along a path proved to be a salient intervening variable in acquiring spatial knowledge for both DE and MM; when the number of turns and intersections along a path increased, both mobile map users and direct experience users drew those paths less often correctly in the sketch maps. Analysis, however, showed that the negative correlation between the number of turns and depiction correctness of path in sketch maps was even stronger for MM participants (Table 6.3, and Figure 6.2). In other words, MM struggled in acquiring topological knowledge of paths even more than DE when the numbers of turns increase along a path; therefore, they drew the paths with more numbers of turns and intersections less often correctly than DE. Previous studies also stated the influence of number of turns on people's topological knowledge of paths; for example, Jansen-Osmann and Wiedenbauer (2004) demonstrated that the roads that were more

complex due to their more numbers of turns along them were drawn less correctly in the sketch maps by residents of the area. The results of this thesis, supported by previous studies, builds up to the argument that complexity of the paths related to their number of turns and intersections has also substantive influence on MM users' spatial knowledge acquisition of path, even more than DE users.

Also, regarding the possible influences of internal/external landmarks on depiction correctness of the paths in the sketch maps, the analysis of this study showed that paths with internal landmarks are depicted more often correctly than the paths without internal landmarks in the sketch maps by DE participants. Also, looking through the sketch maps by DEs and monitoring the drawn paths in relation to the internal landmarks marked along the paths in the sketch maps; it was interestingly noticeable that where a path was drawn, at least, one relevant internal landmark (regardless of the location correctness of the landmark along the path) often accompanied the drawn path. Other studies have also shown that internal landmarks are influential on people's spatial knowledge acquisition of the path (Tversky and Lee, 1999, Klippel and Winter, 2005, Westerbeek and Maes, 2013). Denis (2004) also showed in his research, internal landmarks have a key role in remembering the paths. Research has shown that internal landmarks have at least two functions in navigation; first, they serve as sub-goals that keep people connected to both the point of origin and the destination along a specified path of movement (Allen, 2000). Second, Internal landmarks or 'segment landmarks'(Herrmann et al., 1998) are used for reassurance and confirmation; people use them along the path to make sure they are in the right way to their destinations. The analysis in this study confirm the previous studies and also demonstrates that DE participants in our study had better topological knowledge of the paths with internal landmarks comapre to those without internal landmarks, as evidenced by sketch maps depicting the paths with internal landmarks more often correctly compare to the paths without internal landmarks. However, our analysis showed that having an internal landmark along a path does not seem to have a significant effect on MM users' topological knowledge of the path, as shown there was not a significant difference between the extent of which the paths with internal landmarks are placed correctly in the sketch maps to the paths without internal landmarks. There could be several possible reasons that while internal landmarks can help with DEs' topological understanding of the path, they do not have a significant effect on MMs' topological understanding of the path: First, People using MM are busy working with

their devices, so they simply can miss seeing a landmark on their way. Second, they do not find it necessary to learn the environment by paying attention to their surroundings, as they rely on the device to take them to their destinations. Third, this reason is related to design of mobile map systems; with the knowledge that there are different types of GPS-based systems for pedestrian navigation (auditory, text, maps and etc.), the mobile maps, such as Google Map that most people use them, do not indicate the location of a specific landmark on the mobile maps. Knowing about this fact that citing landmarks along the path on mobile maps can facilitate traveler gaining accurate path knowledge, mobile map designers should think of the ways to improve their designs.

Moreover, regarding the path with external landmarks, the analysis of this study did not show that having a visible external landmark for a path can have a significant influence on depicting the path correctly in the sketch maps for both DE and MM. External landmarks help with general orientation but do not have a significant effect on topological knowledge (Evans et al., 1984b). For example, in the study by Evans et al., that analysed the effects of pathway configuration and landmark on spatial knowledge acquisition, the paths with internal landmarks were drawn more accurately than the paths without internal landmarks and external landmarks.

Furthermore, the analysis in this study showed that complex paths (i.e. path with more than 3 turns) are depicted significantly more often correctly in the sketch maps by DE group when they have an internal landmark compare to the complex paths without internal landmarks. However, for MM users, there was not a significant difference in correctness drawing of complex paths with internal landmark and without internal landmarks. This suggests that placing landmark along the complex path can potentially increase the legibility of the path and help DE travelers to comprehend the complex paths better. In general, a more adequate test of the importance of external and internal landmarks would need to include spatial knowledge acquisition in navigation. It should also be studied how different locations of internal and external landmarks in relation to the path can affect spatial knowledge acquisition of path for both DE and MM. This is an issue worthy of future research.

Nodes:

Regarding nodes; intersections and decision points are challenging in wayfinding, particularly when people are unfamiliar with the environment. The level of complexity for an intersection depends on the number of equivalent choices that one has at a decision point on

the way to find a destination (Richter and Klippel, 2004, Haque et al., 2006, Richter, 2009). O'Neill (1991a) also suggests that the presence of more options at decision points impairs the ability to navigate effectively. When the number of paths increases at an intersection, the ambiguity degree increases as well, for example, when the intersection is only made of three paths like T junction (two choices), the complexity is less and the probability of making a mistake to pick a road is less. This complexity at an intersection has a direct correlation with spatial knowledge acqusition (Richter and Klippel, 2004). The analysis in this study, also confirmed this and showed that there is a consistent negative trend between the extent of which a node is drawn correctly in the sketch maps (by both DE and MM) and increasing number of paths at an intersection, which are referred to node-legs. The nodes that had more number of legs were depicted less often correctly in the sketch maps by the two groups. Having said that, the negative correlation between the numbers of node-legs and depiction correctness of nodes in sketch maps was also stronger for MM participants, meaning, they performed poorer (than DE participants) in drawing the nodes, when the node-legs was more.

Research suggests some aspects that can decrease the ambiguity level of an intersection, one of which is the placement of landmarks at an intersection which can reduce the ambiguity (Sorrows and Hirtle, 1999, Haque et al., 2006). Klippel and Winter (2005) analysed the possible locations of a landmark with respect to the physical layout of an intersection and discussed that the placement of landmarks at the decision points (node-landmark) have considerable effects on the legibility of the node and people‘s spatial knowledge accuracy. The analysis in this study also showed that the nodes that have landmarks at their corners, were depicted more often correctly in the sketch maps by both groups. Furthermore, this study tested to find if the existence of landmarks at complex nodes (Nodes with more than four node-legs) can have any influence on depiction correctness of them in the sketch maps for both groups. Analysis then showed that complex nodes with landmarks were drawn more often correctly than complex nodes without landmarks in the sketch maps for both groups. So the analysis in this study using sketch maps showed that placing landmarks at complex nodes can help both DE and MM to have a better mental representation of them.

Landmarks:

Regarding landmarks, visibility is considered as an important factor in the construction of a cognitive spatial representation and to ease of wayfinding as forming the image of the place for people is partly dependent on remembering some visual landmarks and makes a spatial

relationship between them. The degree to which a person could observe his/her initial location and destination and observe the various landmarks along the route are aspects of visibility that potentially affect the ability to make a cognitive spatial representation of a given environment and quality of spatial knowledge (Shah and Miyake, 2005, Omer and Goldblatt, 2007). In this study, the visibility of the landmarks were measured by using Appleyard scale with three component attributes, namely, immediacy, proximity to the main decision points, and significance of the viewpoint. In three contributes of visibility, all three contributes (immediacy, proximity to the main decision point, and significance of the viewpoint) showed high correlations in correctly depicting the landmarks in sketch maps by DE participants. However, for MM participants, only proximity to the main decision points received the highest correlations in correctly depicting the landmarks in sketch maps.

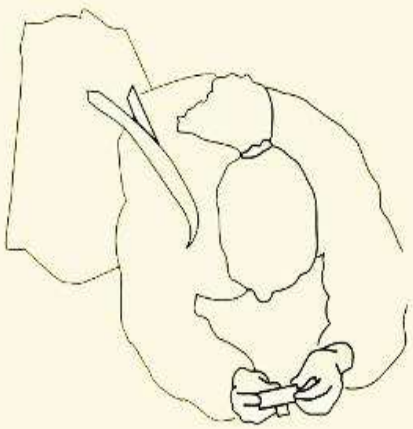
Immediacy: The immediacy of the landmark to the viewing line of the traveller, and its closeness to the centre of vision was found an attention drawing factor for DE participants. Analysis showed that the landmarks happened to be at the vision line of the traveller, as far as they were not too far away, were very likely to be depicted more often correctly in the sketch maps by DE participants. However the same landmarks, which were also at the view line of MM participants, went mainly unnoticed and the probability of depiction correctness of those landmarks in the sketch maps was low. For example, St Nice Church, and Britannia hotel were all on the axis line of vision, or crossed axis line while the travellers were turning (for all the participants- MM and DE). But they were received high attention only from DE participants and were depicted more often correctly in the sketch map by them, while these landmarks were mentioned in the sketch maps very rarely by MM participants.

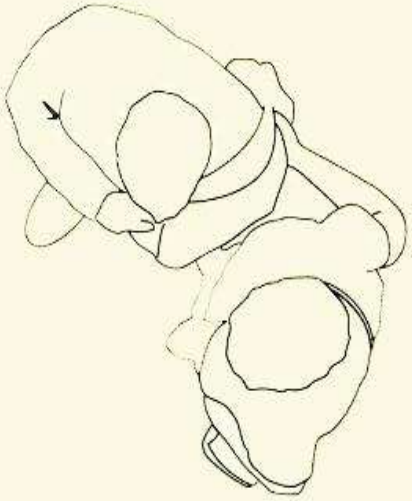
Significance of the viewpoint: This attribute was measured by estimating the number of pedestrians during a typical day that are likely to pass by the viewpoint of the landmarks that the participants passed by in the experiment. This was an approximate measure, as accurate flow data did not exist (Hassan, 1965, Appleyard, 1969). The analysis demonstrates that there is a correlation between the significance of the viewpoint for the landmarks and their depiction correctness in the sketch maps by DE. Landmarks which were located at the main streets and were likely to be seen by more number of people in a typical day, were likely to be depicted correctly in the sketch maps by DE participants as well. However, for MM participants, many of the

landmarks, which had high significant viewpoint and were drawn often correctly by DE participants, went unnoticed.

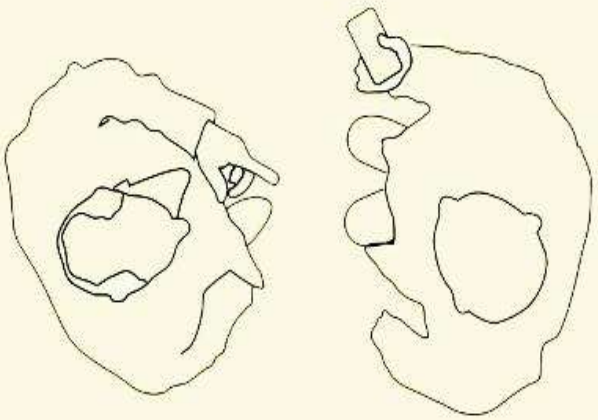
Proximity to the main decision point: Correlation analysis confirmed that the landmarks that are at the decision points, such as intersections and turns were very likely to be depicted correctly in the sketch maps by both DE and MM. As Appleyard (1969) stated this shows the "readiness" of the travellers to see buildings at decision points. It was also interesting to notice that many buildings which received high score (were depicted correctly) at the decision points were not significant in their architecture styles; the Marks and Spencer shop which entrance opened at an intersection, the Starbucks at the corner of wheelchair St. and a small pub at the intersection of Maid Marina way received high attention and were placed so often correctly in the maps. However similar buildings or even some significant buildings which were in other location did not received attention and were drawn rarely correctly in the sketch maps. The highlight point is that 'Proximity to the main decision point' was the only attribute of visibility which was found to be significantly influential on depiction correctness of the landmarks in sketch maps by MM users. This shows that despite the fact that mobile map users pay less attention to their surrounding (Willis et al., 2009), they are more alert at the decision points as they try to adjust what they see in the mobile maps with what they see in real world in order to find the correct way. Interestingly, in a neuroscience study by Javadi et al. (2017), they used fMRI to scan the brains of the participants who used similar systems to mobile maps for navigation. It was shown that their hippocampus in the brain which is in charge of cognitive tasks in navigation were more active at the decision points. This shows that although mobile map participants can be passive navigators (Willis et al., 2009) in their journeys, but at the intersections they are likely to pay attention a bit more to their surroundings.

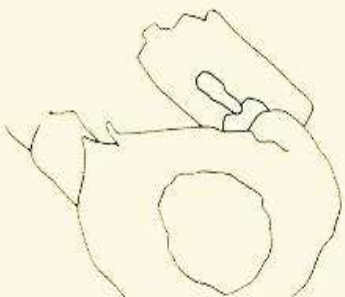
Although visibility to the landmarks is known as the important factor influencing people's mental representation of the physical environment, the physical features of landmarks can have a significant effect as well (Appleyard, 1969, Evans et al., 1984a). This is interesting to find the extent of which landmark physical features such as size, architecture significance, and singularity of the buildings could be influential on MM participant's spatial knowledge acquisition. This is studied in this thesis and the results of that will be presented in the next chapter.

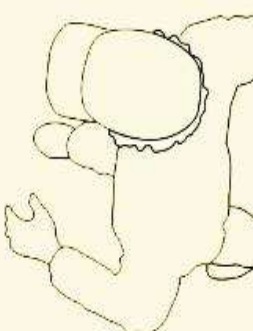




7. Analysis of Photo Recognition Test, Results and Discussion







7.1. Introduction

In order to follow the aims of the thesis and answer the research questions of the thesis, the objectives of this chapter are firstly to investigate how different is the visual knowledge of the buildings between mobile maps users (MM) and direct experience users (DE), and secondly how are the effects of physical-spatial features of the buildings on visual recall of the buildings among MM and DE. This was tested by using a photo recognition test, as explained in Methodology chapter (chapter 5).

7.2. Analysing the results of the photo recognition test

The data collected from the photo recognition test were examined in two phases; the first phase compares the visual recall of the buildings between the two groups, MM and DE. The second phase then determines the physical characteristics of the buildings that contribute to the recall of the buildings for both MM and DE participants.

First Phase:

First, in the photo recognition test, the participants rated the photos, which depicted the buildings of the site, based on a 5 point Likert scale. They rated the photos according to the extent to which they could remember the buildings, so '1' means 'definitely remember' and '5' means 'don't remember at all'. Second, in order to compare the level of photo recognition test between the two groups, a photo recognition score was calculated for each participant, in both groups, by summing up the rates given to the 68 buildings by the participant. Third, an independent t-'t tests' (two-tailed) was applied to compare the mean score obtained for photo recognition test across the two groups (Table 7.1).

7.1. Photo recognition scores for Mobile Map Group (MM) and Direct Experience Group (DE)

	MM		**DE**		**ΔM**	**t**	**df**	**p-value**	**Cohen's d**
	M (SD)	Range	M (SD)	Range					
Participant Photo Recognition Score	245 (24.20)	120-310	124.5 (45.65)	90-210	120.5	-7.1	74	0***	Very large effect

***p≤0.001; **p≤0.01; *p≤0.05; n.s. =not significant (p>.05).

As shown in table 7.1, there is a significant difference in Participant's Photo Recognition Score between the two groups, Mobile Map Group and Direct Experience Group (M MM=245, SD=24.20, and M DE=124.5, SD=45.65, P<0.001). This indicates that those who used mobile maps recalled the buildings of the site, depicted in the photos, significantly less

surely than those who navigated the site through direct experience, or in other words, direct experience group recalled the buildings of the site significantly better than mobile map participants.

The second phase determines the physical characteristics of the buildings that potentially can differentiate the building recognition between the two groups.

Second phase:

In order to identify the physical characteristics of the building that contribute to the recall of the building; first, the level of recall for each building was calculated. Second, the level of recall of each building was compared between the two groups. In doing so, a series of Mann-Whitney U tests were conducted. This test is appropriate when variables fall under two experimental conditions and when participants have been separated into independent groups (Field, 2013), (i.e. Mobile Map group and Direct Experience group) . A Mann-Whitney U test, is also suitable when the dependent variable (i.e., photograph recall task) is measured at discrete level of measurement (i.e., likert scale). In addition, graphical (e.g. Q–Q plot) and statistical inspection (e.g. Shapiro–Wilk and Kolmogorov–Smirnov tests) of the data exposed that the sampling distribution around the mean for the two groups was not normally distributed, thus one of the assumptions for a parametric test failed (Heiman, 2011), so a Mann-Whitney U test, which is a non-parametric test, is suitable to compare the means of the two groups.

In consideration of the family-wise error rate caused by the significance levels required to reject the null hypothesis (i.e., 0.05, 0.01, 0.001) from inflating across the 68 paired comparisons with the same hypothesis(Cabin and Mitchell, 2000) , Bonferroni corrections were used. However, it is important to mention that, although Bonferroni corrections protect statistical significance (p-values) against Type I (family-wise) errors, they may introduce Type II errors (i.e., reduced statistical power) due to their over-conservative calculations(Cabin and Mitchell, 2000, Reiner et al., 2003) . Therefore, the emphasis of inferential tests was mainly placed on ‘effect sizes’ (i.e. a standardised measure of the magnitude of the observed difference between sample groups) and not only on its statistical significance (which, particularly for uneven sample groups could confound effect size and sample size) (Kent et al., 2015). Effect sizes are independent from the sample size and shows

whether the predictor variable has any real significance (Cohen, 1965). In this research, calculation of effect size was completed by analysing the equivalence between the standardised measure of the observed difference and the Pearson's coefficient r based on the following formula (equation). In this formula, N is the number of observations, and the test statistic (Z-score) was extracted from the Mann–Whitney U.

$$\textbf{Effect Size} = \frac{\mathbf{Z_{scores}}}{\sqrt{\mathbf{N}}} \qquad \text{Equation 7.1 : Effect Size}$$

The results of effect size calculation were interpreted according to Ferguson's table (Ferguson, 2009). Benchmark values are given for 'small', 'moderate' and 'large' effect sizes ($r \geq 0.20$, 0.50 and 0.80, respectively). Values below 0.20 were considered as not substantive (i.e. 'negligible') and, thus do not present a practically relevant effect. Table 7.2 presents the results of Mann-Whitney U test which was used to compare the level of building recall for each 68 buildings between the two groups, MM and DE. This table provides the Mean (M) and the standard deviations (SD), the difference between the mean (ΔM), p-value, the result of U test statistic and effect size (r).

Table 7.2. Mann–Whitney U test for comparing the level of landmark knowledge between MM participants and DE participants

Building	MM M (SD)	DE M(SD)	ΔM	U test	*p*-value	Effect size (r)
Building1	1.00 (0.00)	1.00 (0.00)	0.00	756.00	1.00 n.s.	0.00
Building2	1.00 (0.00)	1.00 (0.00)	0.00	756.00	1.00 n.s.	0.00
Building3	1.39 (0.50)	1.29 (0.46)	0.10	678.00	0.34 n.s.	-0.11
Building4	1.67 (0.95)	1.48 (0.86)	0.19	666.50	0.29 n.s.	-0.12
Building5	3.75 (1.70)	2.33 (1.90)	1.42	504.00	0.01 n.s.	-0.32
Building6	4.50 (0.88)	4.33 (0.75)	0.17	630.00	0.15 n.s.	-0.16
Building7	4.75 (0.44)	2.50 (1.4)	2.25	157.500	0.00***	-0.72

Building8	5.00 (0.00)	2.50 (1.8)	2.50	252.000	0.00***	-0.67
Building9	4.75 (0.44)	4.17 (1.4)	0.58	661.500	0.20 n.s.	-0.14
Building10	4.14 (0.87)	2.10 (1.16)	2.04	157.000	0.00***	-0.70
Building11	4.33 (1.75)	2.33 (1.18)	2.00	150.000	0.00***	-0.71
Building12	4.25 (0.70)	2.38 (1.18)	1.87	150.000	0.00***	-0.68
Building13	2.33 (1.25)	2.31 (1.30)	0.02	740.500	0.87 n.s.	-0.01
Building14	4.42 (0.85)	2.62 (1.41)	1.80	247.500	0.00***	-0.60
Building15	4.50 (0.60)	2.55 (1.40)	1.95	208.000	0.00***	-0.64
Building16	4.44 (0.88)	3.36 (1.52)	1.08	446.000	0.001***	-0.38
Building17	2.67 (0.86)	1.81(1.08)	0.86	385.500	0.00***	-0.44
Building18	1.86 (1.1)	1.38 (0.73)	0.48	563.500	0.025**	-0.25
Building19	1.03 (0.16)	1.00 (0.00)	0.03	735.000	0.28 n.s.	-0.12
Building20	4.75 (0.43)	2.50 (1.40)	2.25	157.500	0.00***	-0.71
Building21	4.25 (0.84)	2.10 (1.16)	2.15	135.000	0.00***	-0.72
Building22	2.42 (1.02)	2.10 (1.16)	0.32	604.000	0.11 n.s.	-0.18
Building23	1.92 (1.05)	1.50 (0.74)	0.40	594.000	0.07 n.s.	-0.20
Building24	4.31 (.71)	2.32 (1.05)	1.99	572.500	0.00***	-0.52
Building25	4.33 (1.75)	2.38 (1.18)	1.95	150.000	0.00***	-0.70
Building26	4.00 (.71)	2.44 (1.75)	1.58	400.500	0.00***	-0.52
Building27	2.22 (1.36)	1.95 (1.10)	0.27	685.000	0.45 n.s.	-0.09
Building28	4.00 (0.72)	2.50 (1.8)	1.50	441.000	0.00***	-0.37
Building29	4.75 (0.44)	2.62 (1.41)	2.13	247.500	0.00***	-0.74
Building30	4.52 (0.70)	2.52(1.41)	2.00	202.500	0.00***	-0.68

Building31	4.31 (0.82)	3.98 (1.13)	0.33	649.500	0.25 n.s.	-0.13
Building32	4.25 (0.84)	2.50 (1.01)	1.75	166.500	0.00***	-0.69
Building33	1.78 (0.95)	1.52 (0.77)	0.26	651.000	0.24 n.s.	-0.13
Building34	4.72 (0.45)	2.79 (1.09)	1.93	361.000	0.00***	-0.60
Building35	4.00 (0.71)	2.43 (1.75)	1.57	400.500	0.00***	-0.42
Building36	4.75 (0.43)	2.55 (1.40)	2.20	157.500	0.00***	-0.71
Building37	4.39 (0.8)	2.38 (1.35)	2.01	199.000	0.00***	-0.65
Building38	4.36(0.52)	3.74(1.14)	0.62	530.500	0.01**	-0.27
Building39	4.75(0.43)	2.50 (1.4)	2.25	157.500	0.00***	-0.71
Building40	1.94(1.14)	1.43(.83)	0.51	548.500	0.02*	-0.27
Building41	4.33(0.71)	2.79 (1.09)	1.54	361.000	0.00***	-0.62
Building42	4.75(0.43)	2.55 (1.40)	2.20	208.000	0.00***	-0.74
Building43	1.69(0.95)	1.48(0.85)	0.21	647.500	0.21 n.s.	-0.14
Building44	4.72(0.51)	2.50(1.40)	2.22	164.500	0.00***	-0.70
Building45	1.83(0.97)	1.52(0.77)	0.31	625.000	0.14 n.s.	-0.16
Building46	1.81(1.00)	1.38(0.73)	0.43	570.500	0.03*	-0.23
Building47	4.97(0.16)	2.50(1.82)	2.47	259.000	0.00***	-0.66
Building48	1.03 (0.16)	1.00 (0.00)	0.03	735.000	0.28 n.s.	-0.12
Building49	4.53(0.62)	2.52(1.41)	2.01	202.500	0.00***	-0.64
Building50	4.25(0.84)	2.07(1.15)	2.18	130.500	0.00***	-0.73
Building51	2.28(1.20)	2.26(1.25)	0.02	747.500	0.93 n.s.	-0.01
Building52	4.19(0.92)	2.50(1.00)	1.69	190.000	0.00***	-0.66
Building53	4.31(0.82)	2.38 (1.35)	1.93	199.000	0.00***	-0.65

Building54	4.11(0.70)	3.86(1.00)	0.25	680.500	0.42 n.s.	-0.09
Building55	3.75(1.67)	2.33(1.90)	1.42	504.000	0.00***	-0.32
Building56	4.75(0.43)	2.55(1.40)	2.20	157.500	0.00***	-0.71
Building57	4.44(0.70)	2.36(1.35)	2.08	180.000	0.00***	-0.67
Building58	4.08(0.70)	2.36(1.70)	1.72	361.000	0.00***	-0.46
Building59	4.06(0.71)	2.36(1.50)	1.70	362.000	0.00***	-0.46
Building60	4.75(0.42)	2.45(1.40)	2.30	157.500	0.00***	-0.71
Building61	1.94(1.14)	1.43(0.83)	0.51	548.500	0.01**	-0.26
Building62	2.00 (1.1)	1.45(0.80)	0.55	554.500	0.02*	-0.26
Building63	4.75(0.43)	2.55 (1.40)	2.20	157.500	0.00***	-0.71
Building64	4.44(0.84)	2.62(2.62)	1.82	241.000	0.00***	-0.61
Building65	4.28(0.70)	3.57(1.51)	0.71	606.000	0.11 n.s.	-0.18
Building66	1.92 (1.16)	1.55 (0.80)	0.37	627.500	0.14 n.s.	-0.16
Building67	4.11(0.70)	2.50(1.82)	1.61	427.000	0.00***	-0.39
Building68	4.72(0.51)	2.45(1.41)	2.27	164.000	0.00***	-0.71

Bonferroni corrections: ***$p \leq 0.00001$; **$p \leq 0.00015$; *$p \leq 0.00074$; n.s.=not significant ($p > 0.00074$).
r<.20=negligible; 0.20≤r<.50=small; 0.50≤r<.80=moderate; r≥0.80=large

The statistical analysis of the photo recall test showed that in 41 buildings, DE participants had significantly 'a better performance'($p \leq 0.00001$);the differences detected for these 41 buildings have a generally substantive effect size, mostly 'moderate' ($0.50 \leq r < 0.80$ in 33 cases out of 41) and some 'small' cases ($0.20 \leq r < 0.50$ in 8 cases out of 41) (Table 4); in 20 building photos, both MM and DE participants had equivalently 'a good performance' ($1 \leq M \leq 2.5$), ($p > 0.00074$) ; and in 7 building photos, both groups had 'a poor performance'($2.5 > M \geq 5$), ($p > 0.00074$). Figure 7.1 demonstrates the buildings examples of these three groups. Also, figure 7.2 boxplots the major differences in remembering the buildings between MM participants and DE participants for four selected buildings out of 41 buildings as an example.

Figure 7.2. Boxplots demonstrating the major differences in remembering the buildings between MM participants and DE participants for four selected buildings out of 41 buildings as an example

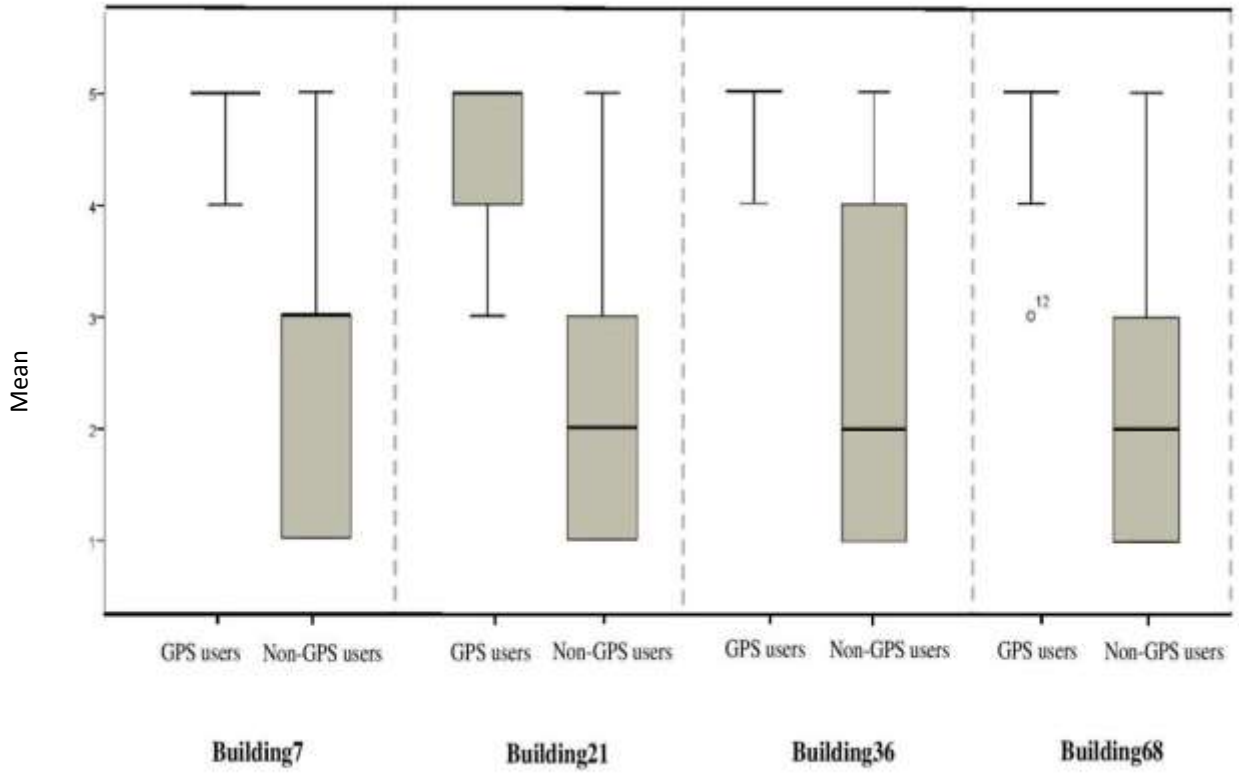


Figure 7.1. demonstrates examples of buildings from the three 'building groups'

Buildings were remembered significantly better by DE than MM

Buildings were remembered well by both groups (at the same rate by both groups)

Buildings were remembered poorly by both groups (at the same rate by both groups)

7.3. Factors contributing to the recall of the buildings (Discriminant analysis)

The results of the photo recall test showed that DE participants had better visual knowledge of the buildings in the site. Subsequently, discriminant analysis was conducted to identify the physical characteristics of the buildings differentiating the recall of buildings for 'MM participants' and 'DE participants'.

Discriminant analysis is a method of extracting features which preserve class separability and has been used to determine which variables discriminate between two or more naturally occurring groups (Cai et al., 2007, Sarabia-Sánchez et al., 2014). As a first step to apply discriminant analysis, two groups were formed based on the results of the photograph recall task: 'the buildings recalled significantly better by DE partcipants ($p \leq 0.00001$) with 41 observations and 'the buildings recalled well, at the same rate, by both DE and MM groups ($p > 0.00074$, $1 \leq M \leq 2.5$) with 20 observations. Then, discriminant function analysis was applied to predict group membership from a set of predictors. The buildings were tested against a number of predictors (physical features): size, shape, signage, maintenance quality, texture, style, contour, colour/texture, visibility from roads, symbolic significance, use intensity, naturalness, siting characteristics, uniqueness of function, and type of nearby road. The building features were then scored based on a three-point rating scale determined by two independent observers unaware of the purposes of the study. Inter-rater reliability exceeded 0.90 for each building characteristic score.

7.3.1. Data testing

Discriminant analysis is robust regarding normality and multicollinearity when the size of the sample is large and degrees of freedom are equal to or more than twenty, however, it is extremely sensitive to the outliers in the data set (Klecka, 1980, McLachlan, 2004, Lane, 2008). The number of observations for any of the two groups must exceed than the number of predictor variables tested as one of the assumptions of this test; in the data set for this study, the smallest group- the buildings recalled at the same rate by both DE participants and MM participants- has 20 observations which is more than the number of predictors employed in this study. The data set in this study (in terms of sample size, number of predictors and etc.) is very similar to the popular study by Evans et al. (1984a). They used discriminant analysis to find the characteristics of the building differentiating the recall of buildings between young and elderly adults. Moreover, as the main goals of discriminant analysis are classification and

inference, homogeneity of variance–covariance matrices must be examined (Tabachnick et al., 2001). Therefore, tests for multicollinearity, normality, and variance–covariance matrices homogeneity were run on the 15 independent variables of this study to verify data quality.

The pooled within-groups correlation matrix was used to detect multicollinearity. This test showed that the correlation coefficients for all the variables are not larger than 0.8 (the largest one was 0.61 between sitting and naturalness) and therefore there is no significant correlation among the variables in both groups and multicollinearity of the variables is low. Furthermore, Box's M test for homogeneity of variances/covariances was run and determined no significant difference ($p = 0.1$) between the two matrices.

Another assumption for the discriminant model is that data values should be from a normal distribution. However, normal assumptions are usually not "fatal" and the resultant significance tests may still be reliable (Poulsen and French, 2008). For this research, graphical (e.g. Q–Q plot) and statistical inspection (e.g. Shapiro–Wilk and Kolmogorov–Smirnov tests) of data showed that the independent variables are all normally distributed.

7.3.2. Discriminant analysis outputs

The linear discriminant test was run and determined that the discriminant function significantly discriminates the groups, Wilks Lambda= 0.27, Chi-square = 51.40, $p \leq 0.001$. Also, the differences between the two groups account for 92% of the variance in the predicting variables since the percentage of explained variance is calculated as [1− (Wilks' λ)] 100. Moreover, the discriminant function analysis yielded a composite of building features that significantly distinguished between two groups of buildings. The building characteristics that contributed significantly to the function discriminating between the two groups of buildings found to be 'style', 'contour' and 'significance of building'. They have large Canonical Coefficients, .78, .65 and .50 respectively and large correlation in Canonical Structure Matrix, .84, .43 and .44 respectively (the outputs of the discriminant analysis are illustrated in Table 6). The standardised canonical discriminant coefficients can be used to rank the importance of each variable and it is likely that the groups differ a lot on a variable that it has a high standardised canonical discriminant coefficient. The canonical structure matrix, which shows the correlations between each variable in the model and the discriminant functions, should be used to assign meaningful labels to the discriminant functions. Mostly, any variable with a correlation of 0.3 or more is considered to be important.

Table 7.3. Outputs of discriminant analysis

	Group1: **Buildings remembered at the same rate by MM and DE participants**	**Group2:** **Buildings remembered significantly stronger by DE participants**	**Standardised** **Canonical Coefficients (weight)**	**Canonical Structure Matrix**
	M (SD)	M(SD)		
Size	1.74 (0.73)	1.83 (0.60)	-0.02	-0.05
Shape	1.58(0.50)	1.10(0.30)	0.17	0.265
Contour	2.11(0.81)	1.40(0.56)	0.651	0.338
Material	1.42(0.70)	1.23(0.51)	0.015	0.097
Movement	2.11(0.66)	2.17(0.70)	-0.077	-0.027
Maintenance	1.42(0.51)	1.73(0.70)	-0.346	-0.150
Signage	1.37(0.60)	1.53(0.68)	0.103	-0.076
Style	2.63(0.50)	1.23(.51)	0.778	0.840
Naturalness	1.37(0.60)	1.33(0.61)	-0.238	0.018
Siting	1.47(0.77)	1.37(0.56)	0.100	0.050
Viewpoint	1.68(0.75)	1.93(0.78)	0.327	-0.097
Intersection	1.95(0.705)	2.23(0.86)	0.305	-0.107
Circulation	1.95(0.70)	2.37(0.76)	-0.395	-0.170
Singularity	1.85(0.78)	1.37(0.61)	-0.068	0.102
Use	1.95(0.70)	1.80(0.71)	-0.070	0.062
significance	2.26(0.93)	1.23(0.50)	0.505	0.442

The results for the canonical discriminant function were: Eigenvalue= 2.73;
Wilks' $\lambda = .268$; $\chi^2=51.4$; $p < 0.001$

The discriminant analysis also revealed that for both groups a high percentage of the cases were correctly classified: 93.3 for buildings remembered stronger by DE participants, and 89.5 for buildings remembered at the same rate by both groups. Overall, 91.8% of the original cases were correctly classified (Table 7.4).

Table 7.4. Classification Summary

Classification Results[a]

Groups			Predicted Group Membership		Total
			buildings recalled at the same rate by both groups	buildings remembered better by DE	
Original	Count	buildings recalled at the same rate by both groups	17	2	19
		buildings remembered stronger by DE participants	2	28	30
	%	buildings recalled at the same rate by both groups	89.5	10.5	100.0
		buildings remembered stronger by DE participants	6.7	93.3	100.0

a. 91.8% of original grouped cases correctly classified.

From this discriminant analysis, it can be concluded that building characteristics particularly salient to

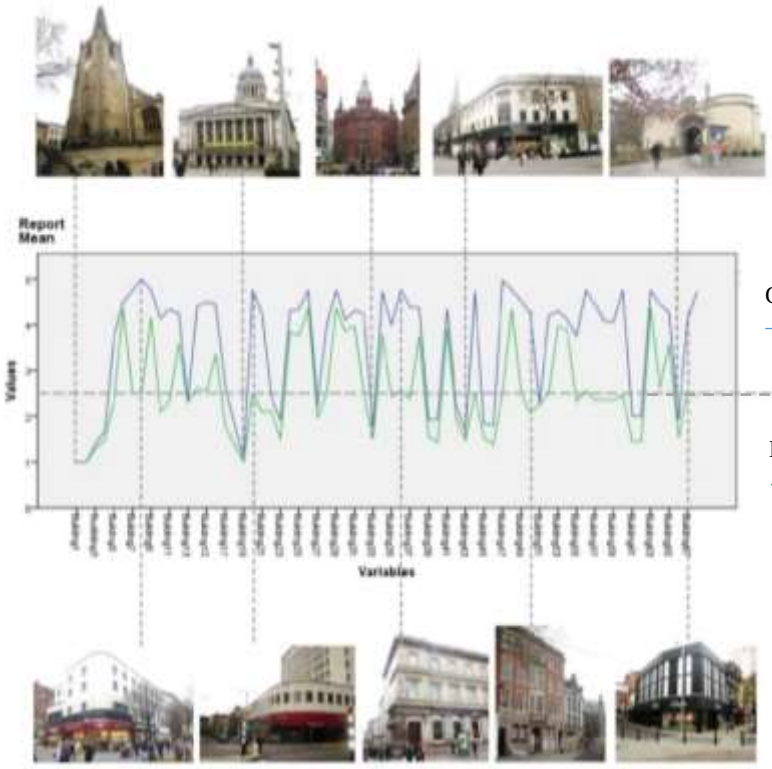
Mobile map participants include: major symbolic significance; unique style; and contrast to background/context. Indeed, buildings with these physical characteristics were recalled strongly by both MM and DE participants. Buildings lacking these features were recalled better by DE participants (Table 7.5).

Figure 7.3 illustrates the mean recall of each building for both groups and shows that DE participants recall most of the buildings better than MM participants and photographs of some of the buildings that were recalled equally strong by both MM and DE participants and buildings that were recalled better by MM participants are also shown.

7.5. Characteristics of the building that were well remembered by mobile map users

Characteristics of the building that mobile map users remembered well	major symbolic significance
	unique style
	contrast to background/context
Buildings lacking these characteristics were remembered better by direct experience users	

Figure 7.3. Demonstrating the level of recall of 68 building (Mean) for MM and DE participants



The characteristics of the buildings recalled strongly by both MM and DE participants: **unique architectural qualities, and/or are significant (historically and culturally) and/or contrast with their physical context**

GPS users

M=2.5

Non-GPS users

The buildings that have less unique architectural qualities, and/or are less significant (historically and culturally) and/or contrast with their physical context were remembered rarely by MM participants, however, they were remembered stronger by DE participants.

7.4. Discussion

7.4.1. Poor visual knowledge of the buildings for mobile map users

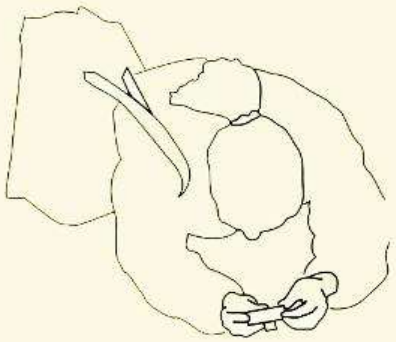
According to the results of this research, mobile map users were able to recall the buildings of the site significantly less surely than DE users. First, this is likely to be because mobile map users receive less information from the surrounding environment while using mobile maps. Discovering a new environment brings many challenges in itself and using GPS devices also requires people to be multi-task within a new environment. So, in addition to reliance on the GPS-based information they will also naturally miss information about the place itself. Second, mobile map navigators, by design, focus on assisting people to reach their destination (from A to B) and do not encode information, landmarks and other features of the physical environment. Their use, therefore, does not require users to recognise and memorise elements of the urban environment (Münzer et al., 2006). As such, people relying on these systems relieve their brain from all navigational tasks (memorising landmarks, conducting route knowledge and cognitive mapping) and therefore learn less about the environment themselves. Through this delegation of the navigational tasks from the brain to the GPS devises, the brain functions weaker in recalling the elements of the site. Significantly, neuroscientists have also discovered that contemporary use of GPS for navigation not only can weaken short-term memory and recalling the elements of the environment but also it may affect how well people's brains function as they age. Indeed, Veronique Bohbot (Neyfakh and So, 2013) found that those who use a GPS system have an excessively higher chance of damaging a region of the brain, known as the hippocampus, involved with memory and navigation. As such, becoming dependent on GPS systems can lead to atrophy of the hippocampus as people age, which puts the person at risk for cognitive problems such as Alzheimer's disease later in life (Iaria et al., 2003). Indeed, Maguire et al. (2000: 2) identify that: "the brain is plastic" and that when people do more navigational tasks, (e.g. memorising elements) they develop better cognitive navigation skills resulting in the part of the brain that encodes navigation tasks becoming stronger. Relying upon GPS for navigation can therefore result in the shrinking and weakening of the hippocampus leading to a further degrading of people's spatial abilities.

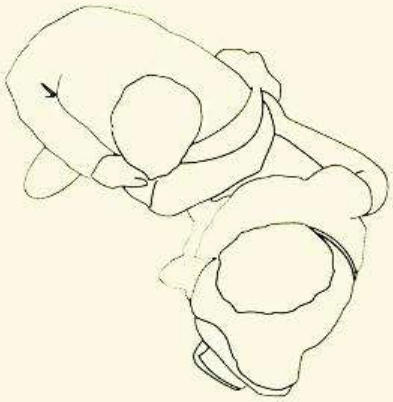
7.4.2. Physical features contributing to building memorability for mobile map users

Another aim of the above analysis was to discover what physical features of buildings better contribute to the recall of buildings amongst mobile map (MM) and direct experience (DE) participants. The analysis of the findings highlighted that the key building features differentiating the recall of buildings between MM participants and DE participants are: 'style'; 'significance of the building'; and 'contour/contrast'. Indeed, the building which had unique style, were historically significant, and outstood against the background were well remembered by both mobile map users and direct experience participants, however, the building did not have this characteristics were remembered better by direct experience participants. From the analysis, it is evident that the style of a building is an important factor in a mobile map user's recall of the buildings. Also, buildings that are historically and culturally significant are better recalled than other buildings by mobile map users, although it could be argued that many significant historic or cultural buildings also tend to have a unique architectural style and differ from their neighbours. Buildings that are similar to majority of the buildings in a street are far less likely to be recalled by MM users and are remembered better by DE participants, whereas buildings that stand out or contrast with their context are also likely to be better recalled by both MM participants and DE participants. These buildings do not necessarily have to be of any great aesthetic quality, for instance one of the better remembered buildings by MM users in this research was under construction and surrounded by scaffolding. This helps to demonstrate that mobile map users can strongly remember only the buildings that are very bold and outstanding and therefore difficult to miss on a journey even whilst following step by step mobile maps instructions.

Significantly, some particular features of buildings appearing to be important in recalling the buildings, which were suggested in a series of studies by Evans (Evans and McCoy, 1998, Evans et al., 1984a, Evans et al., 1984b, Evans et al., 1982), did not show a strong effect in the discriminant analysis. These included factors such as centrality to the circulation system and proximity to a major decision point. Indeed, this research showed that location and the geographical position of buildings did not help mobile map users to better visually remember buildings. The reasons for this may include, as previously mentioned, that when people use mobile maps, they normally tend to follow the route suggested by mobile map system without paying significant attention to their surroundings, and therefore all the given features on the map have the same level of priority. Also, mobile map users will be guided from A to B through the shortest route and they will not pass necessarily by the main junctions and

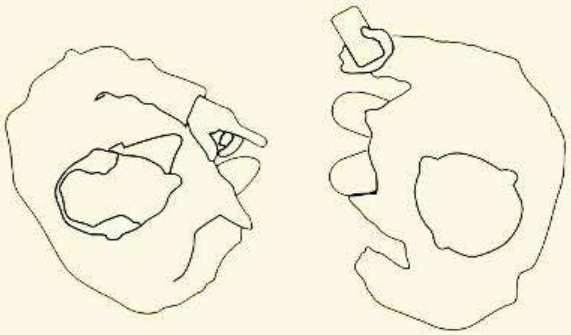
streets. However, when people do not use mobile map and find a route based on their own spatial knowledge, they are more likely to pass through main routes and main junctions and stop at decision points (junctions) to analyse their surroundings in order to make decisions on the next stage of their journey. Hence they are more directly involved with the task and will consequently better remember buildings at the main decision points. Indeed, looking at the data for direct experience participants in this research, the buildings that are closer to the main decision points are remembered far better than they are by mobile map users.

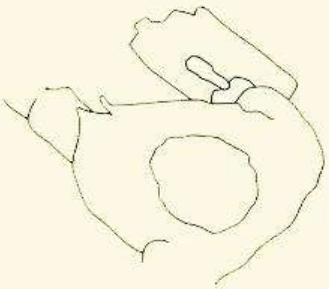


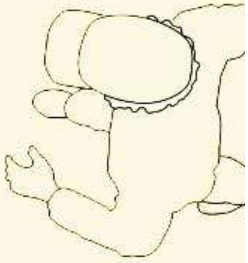


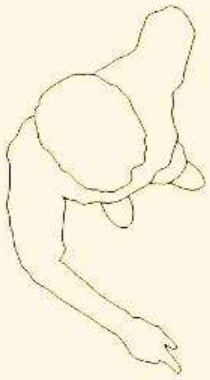
□

8. Conclusions and Future Research









8.1. Summary of findings and discussion

In this chapter, first, the analysis and discussion from the previous chapters are summarised, and second, the contribution of this study are discussed in three main sections: a) the discipline, and profession of urban planning and urban design; b) the design of GPS-based navigation systems; and c) the importance of having cognitive-friendly environments to maintain and improve the cognitive health of the users of the physical environment. Finally, the potential studies for the future research will be introduced.

This thesis aimed to compare spatial knowledge acquisition of people who used a Mobile Map for navigation to those who navigated the environment using 'non-aided' technology (Direct Experience group). It also attempted to find the spatial factors affecting the spatial knowledge acquisition of the both groups, mobile map participants and direct experience participants. In doing so, a sketch map drawing test and photo recognition test were used as to elucidate their acquired spatial knowledge of the site. The results of both the sketch map drawing and photo recognition test indicated that mobile map users have less complete knowledge than direct experience navigators of their real-world environments. The results of the sketch map test showed that the participants who used mobile map for navigation gained less accurate topological knowledge of the site compared to the direct experience participants. The mobile map participants also tended to draw the landmarks, nodes, and paths of the site less correctly in their sketch maps. Moreover, the results of the photo recognition test which examined the participants' visual knowledge of the elements of the site (buildings) demonstrated that the mobile map participants had weaker recall of the buildings within the site than the direct experience participants groups. These results extend previous short-term memory research by showing that deficits in recall in GPS-users experience generalize to both information in a real-world context and the design of navigation systems. These results presented that despite the fact that the use of mobile maps helped the participants to get to their destinations successfully, the devices were not functionally helpful for people to acquire accurate and correct spatial knowledge of the site. This study further analysed the effects of the physical environment on the spatial knowledge acquisition among the two groups; first, the association between the physical spatial features of the elements (landmarks, nodes, and paths) and the extent to which they were depicted correctly in the sketch maps were examined, second, the association between physical features of the buildings presented to the participants in the photo recognition test and the extent to which those buildings were remembered by both groups were tested. The analysis of these results

revealed a number of physical spatial features of the landmarks, nodes, and paths that could be the good predictors for spatial knowledge acquisition of two groups, mobile map participants and direct experience participants. The tables below (table 8.1) and (table 8.2) summarise these physical spatial features of the elements and their effects on spatial knowledge acquisition.

Table 8.1. summarises these physical spatial features of the elements and their effects on spatial knowledge acquisition

Elements	Physical-spatial factors	Spatial knowledge (Topological Knowledge)		Description
		MM	DE	
Paths	Number of Turns	↓(-)	↓	The analysis demonstrated that the greater the number of turns along a street, the less accurate spatial knowledge of the street people gain. This influence is greater on mobile maps users, meaning, mobile map users acquire a less clear image of the streets with greater number of turns ↓(-)
	Length	×	×	The analysis showed that the length of the street/path does not have a significant impact on accuracy/ correctness of spatial knowledge of the street.
	Containing internal landmarks	×	↑	The analysis showed that the internal landmarks along the paths did not contribute significantly in spatial knowledge acquisition of the mobile map users from the streets, however, the internal landmarks did help with building the direct experience users' spatial knowledge acquisition.
	Containing external landmarks	×	×	The analysis demonstrated that the external landmarks along a paths have no significant impact on building the spatial knowledge of none of the groups from the streets.
	Complex Path (great number of turns) with landmarks	↑	↑(+)	The analysis showed that both groups can build up more accurate spatial knowledge from the paths with great number of turns (complex paths) only when they have internal landmark. This effect is greater on direct experience users.
Nodes	Number of Node-Legs	↓(-)	↓	The analysis showed that the greater the number of legs at a node, the more complicated the node, and the more difficult is for the people to make a clear image of the node. This influence is greater on mobile map users.
	Containing landmarks	↑	↑(+)	The analysis demonstrated that participants in both group could have more accurate spatial knowledge of the nodes that they have landmarks (node-landmark). This influence was greater on direct experience users.
	Complex Node (great number of legs) with landmarks	↑	↑(+)	The analysis showed that both groups can have a more accurate image of a complex node only when it has landmarks. This influence is greater on direct experience users.
Landmarks	Immediacy	×	↑	The analysis showed that the landmarks that are placed at the immediate context of the street can be recalled more accurately by direct experience group, however, the immediacy of the landmarks did not show to have a significant influence on recall accuracy of mobile map users.
	Proximity to the decision points	↑	↑(+)	The analysis demonstrated that the landmarks that were closer to the main decision point were more often correctly drawn in the sketch maps by both groups. This influence was greater on direct experience users.
	Significant of viewpoint	×	↑	The analysis showed that the significance of the viewpoint did not have a significant impact on correctness depiction of landmarks in the sketch maps by mobile map users, while the landmarks which had a significant viewpoint were drew more often correctly in the sketch maps by direct experience users.

No Effect: × Upward Effect: ↑ Downward Effect: ↓ Greater Upward Effect: ↑(+) Greater Downward Effect: ↓(-)

Table 8.2 summarises these physical spatial features of the elements and their effects on spatial knowledge acquisition

Physical-spatial factors	Spatial knowledge (Visual Knowledge of buildings)		Description
	MM	DE	
Contour	↑	↑	Analysis showed that the buildings having these physical characteristics can be recalled well by both mobile map users and direct experience users. However, the buildings lacking these characteristics can be recalled significantly better by direct experience users.
Style	↑	↑	
significance	↑	↑	

8.2. The potential implementation of the results in urban design practice

The physical environment is a key determinant in forming people's cognitive map and spatial knowledge. Research has shown that some places can be better comprehended by people, and people can easier build up a clear cognitive map from them, these places are referred to legible places. Research has evidenced that these places have particular characteristics, these characteristics can be divided into two main categories: 1) characteristics concerning with the entirety of the physical environment (such as complexity of a layout, and differentiation between different part of the environment); and 2) Elemental characteristics; characteristics related to the elements of the environments, namely, landmarks, paths, and nodes. These characteristics were extensively discussed in chapter three of this thesis (3.3.1). In this thesis, the focus was placed upon elemental characteristics and as such, the research attempted to find the effects of these elemental characteristics on the spatial knowledge acquisition/cognitive mapping of GPS users.

A potentially important finding of this study is that some spatial features were found to be influential on mobile map users' spatial knowledge acquisition. The effects of the spatial features of the environment on spatial knowledge acquisition are complex but generally consistent with the analysis of this thesis that less complex configuration for paths and nodes (paths with fewer numbers of turns, and nodes with fewer numbers of legs) and the placing of landmarks at main decision-making points facilitates geographic knowledge for both mobile map participants and direct experience participants. Moreover, placing landmarks at the turns of the complex paths and corners of the complex nodes can decrease the ambiguity of them and contribute to the building-up of a clearer image of those paths and nodes for both mobile map users and direct experience users.

Moreover, placing landmarks within the immediate context of the streets can help direct experience users to have a clearer image of the street. Also, providing visual access to the landmarks can assist direct experience navigators to acquire a greater spatial knowledge of these landmarks. Landmarks placed at the decision points can also be recalled better as well as contributing to building-up a clear image of the decision point for both mobile map and direct experience users. This thesis, based on its results, also proposes that a fairly simple urban layout appears to reduce the spatial knowledge acquisition differences between the two groups.

Several features of buildings that showed to be important in recalling the buildings, which were suggested in a series of studies by Evans (Evans and McCoy, 1998, Evans et al., 1984a, Evans et al., 1984b, Evans et al., 1982), did not show a strong influence on building recall of the mobile map users. These included factors such as centrality to the circulation system and proximity to a major decision point. Indeed, this research showed that location and the geographical position of buildings did not help mobile map users to better visually remember buildings. Regarding the visual remembering of buildings, the buildings that stood out against their background, had a unique style, and were architecturally/historically significant were better recalled by both mobile map and direct experience users. The buildings lacking these characteristics were recalled better by direct experience users. The results of this study suggest that the movement for preservation of historical buildings may argue that such buildings, in addition to their historical and cultural significance, provide important orientation functions for people, whether mobile map users or direct experience participants. Also, a special attention should be paid to architectural style and the uniqueness of buildings in the city in order to increase the memorability of these buildings and a better comprehension of the city.

Knowing about these spatial features can help urban planners and urban designers to implement effective measures of legibility, as they seek to create more legible environments (Appleyard, 1969) that support people's understanding of physical environment. If the physical environment does not facilitate the acquisition of spatial knowledge in its entirety and its elements (Allen, 1999a), namely, paths, nodes, and landmarks, by for instance, providing visibility to potential landmarks or controlling the numbers of paths entering an intersection, people may not be able to form a clear image of the environment and thereby face difficulties in their navigation. Also, if the physical environment becomes more complex and less legible, people's tendency to use mobile maps for assistance can increase (Kalin and Frith, 2016). It is a necessary task for urban designers to find the parts of the physical setting that are cognitively confusing for people and to enhance them by designing solutions, such as the placing of a physical installation, or by enhancing the architectural style of the buildings. As Georg Gartner says "If you know at what point people are likely to make spatial discussions or are likely to get lost, you could place a landmark there" (Caquard, 2013, P:46).

8.2.1. Cognitive-friendly environments: Urban Design, Navigation assistance and cognitive health

Wayfinding is the problem-solving task of solving the problem of 'how to get from A to B' in the physical environment. In this task, the brain is technically in charge of solving the problem and in doing so the brain might need the assistance of navigational tools, such as mobile maps, signage, etc. The problem that needs to be resolved in this task is placed within the physical environment. The harder the problem, or the more complex the environment, the greater the challenge for the brain. Also, the more challenges and the bigger challenges the brain has to solve, or in other words, the more effort placed on the brain to solve the problem, the stronger its abilities in solving the problems, or the stronger a person's navigational skills will become. This is consistent with the neuroscience study by Maguire et al. (2006), they discovered that London taxi drivers, who have to navigate one of the most complex street grids in the world, in central London, have a typical brain characteristics and they found that these driver's hippocampus (i.e. a brain region associated with spatial memory) are larger compared to other people. Maguire added that doing more navigational tasks which put more efforts on the brain can strengthen people's hippocampus and their navigational abilities (Shah and Miyake, 2005). Having said that, if the problem is very difficult to solve, in other words, if the physical environment, or a part of that is too complex, not legible, or confusing, people might experience the feeling of getting lost, confusion, and frustration stemming from such pressures. In such situations, they are more likely to use assistant tools such as GPS to find their ways to get help. So this thesis, in order to advocate healthy environments that support people's cognition and mental health, suggests that the physical environment should not be too simple (e.g. simple grid networks) to leave the brain effortless, also they should not be too complex that people get confused and lead to the increased use of navigational assistance. It is necessary that urban designers to be familiar with the characteristics of legible environments backed up with relevant literature, and to be able to apply these to the design of places in order to have cognitive-friendly environments. Indeed, the physical environment should be designed in a way that enables the brain to enjoy the feeling of discovery, excitement, and serendipity, but it should be also easy to comprehend as a whole and in its constituent elements. The key to this aim is to have a balance between complexity and simplicity in the setting, as well as applying the factors of legibility to the design of physical environment.

8.2.2. Design guideline suggestions

According to the discussion above, this research advocates a series of urban design guidelines that can be applied to the design of the physical environment which contribute to having more cognitive-friendly environments that can support people's navigation experience by GPS or without GPS. This can help people to gain more accurate spatial knowledge of the environment and it is elements. These guidelines are as follows:

a) Streets: less complex streets with less turns ; and
   placing landmarks at the turns of the complex streets
b) Nodes: less complex nodes with fewer streets entering these nodes; and
   placing landmarks at corners or near to the corners of the complex nodes.
c) Landmarks: well distributed landmarks in the environment; placing landmarks at the main decision points as well as along the streets for reassurance during navigation.
d) Buildings: well distributed buildings with significant and unique style characteristics which can potentially function as landmarks to contribute to the image of the place and memorability of the buildings and the area.
e) Complexity: having a balance in the level of complexity of the setting; not too simple and not too complex while also offering the chance of surprise and serendipity in people's journeys.

8.3. Implementation of the results in designing navigation systems:

Although, studying the mobile map systems is not the focus of this thesis, during the experiments of the study, several design issues were identified that are presented in this section. With regards to the effectiveness of mobile maps in this study, although the use of Mobile Maps allowed participants to find their way to the destinations as well as the Direct Experience group did, the research highlighted some key issues in mobile map systems that do not help people to gain an accurate spatial knowledge. The first issue is design related. In using mobile maps, people find their goals by receiving a continuous 'spatial updating' of their positions in the place as they move toward their goals. This spatial update that they receive on mobile maps is often at a 'zoomed-in' scale and does not provide the subject with a bigger picture of their surroundings showing the relationship of each element with other elements in the greater area. While other similar 'map-like' assistance for navigation such as physical maps, which are proved to be more effective than mobile maps in helping people to acquire accurate spatial knowledge (Ishikawa et al., 2008, Willis et al., 2009), prepare a fixed

survey representation of the area rather than egocentric experiences. Second, this is also a design-related issue whereby mobile maps do not encode the information and landmarks. Their use, therefore, does not require people to recognise and memorise elements of the urban environment (Münzer et al., 2006). Third, mobile maps turn people into 'passive navigators', whereby people using mobile maps revert to "auto pilot mode" (Turner et al., 2001) and receive the right information for moving within the place to achieve their destinations resulting in little cognitive engagment with the environment. When people are actively engaged in the physical environment, such as when they navigate the environment in a direct experience way, they are stimulated to acquire knowledge about the place in which they are moving. However, when people experience the environment in a passive mode, i.e., being led through the environment without being able to make self-motivated choices, such as when they are using mobile maps, their spatial knowledge acquisition is hindered (Held and Hein, 1963).

There is still room for improvement for the mobile navigation systems such as Mobile Maps becoming a helpful 'navigator' that can support people's spatial knowledge acquisition in way finding. The results of this thesis suggest a series of guidelines to facilitate the better design of mobile maps, including:

a) Enhancing the graphics of the maps in a way that can help people to acquire a greater spatial knowledge of the environment. For example, according to the results of this study, 'breaking down' streets with a great number of turns into clear forms on the map; emphasising/pointing out the landmarks at the turns of the paths which could contribute to the recall of these paths; simplifying the complex nodes by using graphics and emphasising those landmarks located at the nodes to increase the legibility of the nodes for the mobile map users. In this way, the users will be required to notice the relationship between landmarks, paths, turns, and decision points.

b) In order to support the spatial knowledge acquisition of GPS users which is tied with their cognition health, GPS-based navigation systems should provide something more than solely guiding people step by step from point A to B and updating people's positions within the environment. The current interfaces of many GPS-based applications are blank, however highlighting the physical structure of the site (i.e. the main streets and landmarks and the relationship between them by showing the hierarchical order of the streets and landmarks), could be of great assistance to people's comprehension of the structure of the area and in turn

develop their survey knowledge. The desirable version of such interfaces should provide users with an overview of the site (including the main abstract structure, landmarks, and nodes), in which users can understand the relationship of their position to the other elements/places in the site. This could be very similar to what physical maps do through the provision of a wealth of abstract survey knowledge that lets people 'fill-in' the 'blanks' from their own navigational experience, thereby giving their brain the chance to use its abilities. The users of mobile map/GPS-based navigation systems, in the best scenario, will learn the site as step-by-step directions from A to B, as they follow directions from the system, but as they have not formed a proper survey knowledge of the site, they cannot choose an alternative route in the site from their memory that can take them from A to B, or choose a path from memory that can take them to the other parts of the site.

c) Designers of spatial services/systems will need to be aware of all types and categories of landmarks in order to make the service authentic. The data collected in this thesis particularly indicates that personal landmarks have a social and communicative role that should not be precluded by enforcing the most legible landmark forms available. So the systems ought to be capable to be personalised and users can mark the personal landmarks on the map.

d) The ability to individually tailor the orientation of spatial displays would seem crucial from a design perspective. The designers of navigation systems should consider the use of 'north-up' orientation versus 'track-up' displays informed by the spatial mapping literature, but accounting for how a good design could ease distortions in spatial knowledge and enable the development of a good internal representation of different environments. It could appear to matter more where the participants of this study who used mobile map for navigation, could not link the landmarks accurately in their mental maps and could not build up an accurate survey knowledge of the study site in comparison to direct experience participants.

e) Flexibility is required for users of spatial technologies to personalise their neighbourhood profiles. Designers of technologies that draw on spatial measurement to define behaviours or services will need to explore the resolution, overlap and spatial mappings that are being used to collect spatial profiles. All location-based system technologies ought to therefore be capable of being personalised by users.

8.4. A holistic approach toward maintaining peoples' cognitive health

People are increasingly using GPS-based systems for navigation. Researchers are, however, concerned with the effects of using these devices on the brain with many believing that GPS devices cause people navigational skills to atrophy. What is the solution to this issue? GPS-based systems devices are indeed useful and can assist people in different situations (e.g. assist people who have dementia, or helping disabled people, etc.), and none of the researchers identifying these worrying signs of the use of GPS systems have suggested abandoning these devices/sytems. Some neuroscience and psychology researchers have advised that people should use 'GPS systems intelligently', for example, Bohot states that: "If you use it in a way that helps you learn about the environment, then you're exercising your hippocampus. If you're using it in a robotic way, and just listening to the instructions, then you're not" (Stromberg, 2015, P:3). Hugo Spires also suggests that people should limit their use of GPS for navigation by understanding the potential negative effects it could have on their brain (Condliffe, 2017). On the other hand, the technology of navigation system design is becoming more advanced and in turn they are more tempting to use. However, this research suggests that in order to maintain peoples' cognitive health in the era of GPS systems, a holistic approach should be undertaken. In this approach, three factors come into effect: first, the design of the physical environment is an important to preserve peoples' cognitive health. As such, the physical environment should be designed as cognitive-friendly places that facilitate people's cognition. Second, navigation systems should be designed in a way that can help people to acquire a greater spatial knowledge of the environment. And third, people should become aware of the possible negative effects of GPS systems on their brain and navigational skills and therefore use such devices wisely, e.g. using them only when it is necessary, or limiting their use such as using them on the way to their destination, but not on the return journey. Among these factors, the physical environment is a fundamental factor, so if cognitive-friendly environment characteristics are applied to the design of the physical environments, people's need to use navigational assistance for wayfinding will be reduced.

8.5. Future Research:

In the context of this research, importantly, further research needs to be undertaken to understand the optimum type, number and relationship of landmarks (in terms of form, scale, distance, inter-visibility, etc.) to maximise the memorability of them to people. Also, the effects of other characteristics of physical environment on GPS users' spatial knowledge and wayfinding behaviour, and their emotional reaction during the journey should be studied. Such studies can enable researchers to further understand how to maximise the potential for achieving better design for urban places and navigation systems in a way that they support people's cognition and mental health as well as increasing the efficiency of their navigational journey within the physical environment. This research study also encourages architects, urban designers and urban planners to develop a better understanding of how the use of technology is both changing and challenging the way that people relate to the built environment. Indeed, studying peoples' engagement with physical place and how this is affected by technology can lead to the design of physical places and environments that are more responsive to society's contemporary needs and preferences.

Appendix 1

SENSE-OF-DIRECTION TEST (SELF REPORT)

Sex: F M Today's Date: _____

Age: _____ V. 2

This questionnaire consists of several statements about your spatial and navigational abilities, preferences, and experiences. After each statement, you should circle a number to indicate your level of agreement with the statement. Circle "1" if you strongly agree that the statement applies to you, "7" if you strongly disagree, or some number in between if your agreement is intermediate. Circle "4" if you neither agree nor disagree.

1. I am very good at giving directions.

strongly agree 1 2 3 4 5 6 7 strongly disagree

2. I have a poor memory for where I left things.

strongly agree 1 2 3 4 5 6 7 strongly disagree

3. I am very good at judging distances.

strongly agree 1 2 3 4 5 6 7 strongly disagree

4. My "sense of direction" is very good.

strongly agree 1 2 3 4 5 6 7 strongly disagree

5. I tend to think of my environment in terms of cardinal directions (N, S, E, W).

strongly agree 1 2 3 4 5 6 7 strongly disagree

6. I very easily get lost in a new city.

strongly agree 1 2 3 4 5 6 7 strongly disagree

7. I enjoy reading maps.

strongly agree 1 2 3 4 5 6 7 strongly disagree

8. I have trouble understanding directions.

strongly agree 1 2 3 4 5 6 7 strongly disagree

9. I am very good at reading maps.

strongly agree 1 2 3 4 5 6 7 strongly disagree

10. I don't remember routes very well while riding as a passenger in a car.

strongly agree 1 2 3 4 5 6 7 strongly disagree

11. I don't enjoy giving directions.

strongly agree 1 2 3 4 5 6 7 strongly disagree

12. It's not important to me to know where I am.

strongly agree 1 2 3 4 5 6 7 strongly disagree

13. I usually let someone else do the navigational planning for long trips.

strongly agree 1 2 3 4 5 6 7 strongly disagree

14. I can usually remember a new route after I have traveled it only once.

strongly agree 1 2 3 4 5 6 7 strongly disagree

15. I don't have a very good "mental map" of my environment.

strongly agree 1 2 3 4 5 6 7 strongly disagree

Appendix 2

The data collection form which was used for the main study.

Participant No:	**Brain's GPS VS. GPS in the Hands**	

Sex: F M **Date: _____**

Age: _____ **Group: GPS group ☐ Self- experienced group ☐**

1-Sketch map:

Draw a sketch map of the area that you have been through as accurate as you can. Draw the streets, landmarks, all the details that you can remember.

According to the pictures, circle a number to indicate the degree to which you can remember each building. Circle "1" if you surely remember the building, "5" if you do not remember the building at all, or some number in between if your agreement is intermediate.

Buildings	Surely remember	slightly remember	either remember/ neither remember	hardly remember	not remembering at all
	1	2	3	4	5
Building1					
Building2					
Building3					
Building4					
Building5					
Building6					
Building7					
Building8					
Building9					
Building10					
Building11					
Building12					
Building13					
Building14					
Building15					
Building16					
Building17					
Building18					
Building19					
Building20					
Building21					

Buildings	Surely remember	slightly remember	either remember/ neither remember	hardly remember	not remembering at all
	1	2	3	4	5
Building22					
Building23					
Building24					
Building25					
Building26					
Building27					
Building28					
Building29					
Building30					
Building31					
Building32					
Building33					
Building34					
Building35					
Building36					
Building37					
Building38					
Building39					
Building40					
Building41					
Building42					
Building43					
Building44					

Buildings	Surely remember	slightly remember	either remember/ neither remember	hardly remember	not remembering at all
	1	2	3	4	5
Building45					
Building46					
Building47					
Building48					
Building49					
Building50					
Building51					
Building52					
Building53					
Building54					
Building55					
Building56					
Building57					
Building58					
Building59					
Building60					
Building61					
Building62					
Building63					
Building64					
Building65					
Building66					
Building67					
Building68					

Appendix 3

The data collection form which was used for the first pilot study.

Participant No:	**Brain's GPS VS. GPS in the Hands**	The University of Nottingham
Sex: F M	**Date: _____**	
Age: _____	**Group: GPS group ☐ Self- experienced group ☐**	

1-Sketch map:

Draw a sketch map of the area that you have been through as accurate as you can. Draw the streets, landmarks, all the details that you can remember, indicate the north direction as well.

2-Environmental Memory

This section tests the ability of people in remembering the places that they have been through. It tests Landmarks, junctions and streets.

1-Name/Describe the buildings you can remember from the area (as many as you can). Describe their details as much as you can remember.

2- Name/Describe the junctions/squares you can remember from the area (as many as you can). Describe their details as much as you can remember.

3- Name/Describe the streets you can remember from the area (as many as you can). Describe their details as much as you can remember.

2-Environmental Memory

This section tests the ability of people in remembering the places they have been through. It tests Landmarks, junctions and streets.

1-1-Landmarks

Building-1

 **Do you remember this building?**

Degree	Surely remember	slightly remember	either remember/ neither remember	hardly remember	not remembering at all
	1	2	3	4	5
Building-1					

What features of the building help you to remember it? (size, material, colour, function, context of the building,…)

Building-2

Degree	Surely remember	slightly remember	either remember/ neither remember	hardly remember	not remembering at all
	1	2	3	4	5
Building-2					

 What features of the building help you to remember it? (size, material, colour, function, context of the building,…)

Building-3

Degree	Surely remember	slightly remember	either remember/ neither remember	hardly remember	not remembering at all
	1	2	3	4	5
Building-1					

What features of the building help you to remember it? (Size, material, colour, function, context of the building,)

Building-4

Degree	Surely remember	slightly remember	either remember/ neither remember	hardly remember	not remembering at all
	1	2	3	4	5
Building-1					

What features of the building help you to remember it? (size, material, colour, function, context of the building,…)

Building-5

Degree	Surely remember	slightly remember	either remember/ neither remember	hardly remember	not remembering at all
	1	2	3	4	5
Building-1					

What features of the building help you to remember it? (size, material, colour, function, context of the building,…)

Building-6

Degree	Surely remember	slightly remember	either remember/ neither remember	hardly remember	not remembering at all
	1	2	3	4	5
Building-1					

What features of the building help you to remember it? (size, material, colour, function, context of the building,…)

Building-7

Degree	Surely remember	slightly remember	either remember/ neither remember	hardly remember	not remembering at all
	1	2	3	4	5
Building-1					

 What features of the building help you to remember it? (size, material, colour, function, context of the building,…)

Building-8

Degree	Surely remember	slightly remember	either remember/ neither remember	hardly remember	not remembering at all
	1	2	3	4	5
Building-1					

 What features of the building help you to remember it? (size, material, colour, function, context of the building,…)

Building-9

Degree	Surely remember	slightly remember	either remember/ neither remember	hardly remember	not remembering at all
	1	2	3	4	5
Building-1					

 What features of the building help you to remember it? (size, material, colour, function, context of the building,…)

Building-10

Degree	Surely remember	slightly remember	either remember/ neither remember	hardly remember	not remembering at all
	1	2	3	4	5
Building-1					

 What features of the building help you to remember it? (size, material, colour, function, context of the building,…

1-2-Nodes

This part examines your ability to remember the junctions. Below are some of the junctions from the area.

Junction-1

Do you remember this junction?

Degree	Surely remember	slightly remember	either remember/ neither remember	hardly remember	not remembering at all
	1	2	3	4	5
Junction-1					

How do you describe this junction?
Indicate the reasons helping you to remember this junction? (e.g. any particular building or any views from the streets)

Do you remember the corners?

Degree	Surely remember	slightly remember	either remember/ neither remember	hardly remember	not remembering at all
	1	2	3	4	5
Corner-1					
Corner-2					
Corner-3					
Corner-4					

What features of the corner help you to remember it? (Size, material, colour, function, context of the building…)

Do you remember this view?

Degree	Surely remember	slightly remember	either remember/ neither remember	hardly remember	not remembering at all
	1	2	3	4	5
View-1					
View-2					
View-3					
View-4					

Junction-2: Do you remember this junction?

Degree	Surely remember	slightly remember	either remember/ neither remember	hardly remember	not remembering at all
	1	2	3	4	5
Junction-1					

How do you describe this junction? Indicate the reasons helping you to remember this junction? (e.g. any building or view from one of the street)

Do you remember the corners?

Degree	Surely remember	slightly remember	either remember/ neither remember	hardly remember	not remembering at all
	1	2	3	4	5
Corner-1					
Corner-2					
Corner-3					
Corner-4					
Corner-5					
Corner-6					

What features of the corner help you to remember it? (Size, material, colour, function, context of the building…)

Do you remember this view?

Degree	Surely remember	slightly remember	either remember/ neither remember	hardly remember	not remembering at all
	1	2	3	4	5
View-1					
View-2					
View-3					
View-4					
View-5					

Junction-3: Do you remember this junction?

Degree	Surely remember	slightly remember	either remember/ neither remember	hardly remember	not remembering at all
	1	2	3	4	5
Junction-1					

 How do you describe this junction? Indicate the reasons helping you to remember this junction? (e.g. any building or view from one of the street)

 **Do you remember the corners?**

Degree	Surely remember	slightly remember	either remember/ neither remember	hardly remember	not remembering at all
	1	2	3	4	5
Corner-1					
Corner-2					
Corner-3					
Corner-4					

 What features of the corner help you to remember it? (Size, material, colour, function, context of the building…)

 **Do you remember this view?**

Degree	Surely remember	slightly remember	either remember/ neither remember	hardly remember	not remembering at all
	1	2	3	4	5
View-1					
View-2					

Junction-4: Do you remember this junction?

Degree	Surely remember	slightly remember	either remember/ neither remember	hardly remember	not remembering at all
	1	2	3	4	5
Junction-1					

How do you describe this junction? Indicate the reasons helping you to remember this junction? (e.g. any building or view from one of the street)

 **Do you remember the corners?**

Degree	Surely remember	slightly remember	either remember/ neither remember	hardly remember	not remembering at all
	1	2	3	4	5
Corner-1					
Corner-2					
Corner-3					
Corner-4					

 What features of the corner help you to remember it? (Size, material, colour, function, context of the building…)

 **Do you remember this view?**

Degree	Surely remember	slightly remember	either remember/ neither remember	hardly remember	not remembering at all
	1	2	3	4	5
View-1					
View-2					
View-3					
View-4					

Junction-5: Do you remember this junction?

Degree	Surely remember	slightly remember	either remember/ neither remember	hardly remember	not remembering at all
	1	2	3	4	5
Junction-1					

How do you describe this junction? Indicate the reasons helping you to remember this junction? (e.g. any building or view from one of the street)

 **Do you remember the corners?**

Degree	Surely remember	slightly remember	either remember/ neither remember	hardly remember	not remembering at all
	1	2	3	4	5
Corner-1					
Corner-2					
Corner-3					
Corner-4					

 What features of the corner help you to remember it? (Size, material, colour, function, context of the building…)

 **Do you remember this view?**

Degree	Surely remember	slightly remember	either remember/ neither remember	hardly remember	not remembering at all
	1	2	3	4	5
View-1					
View-2					
View-3					
View-4					

Junction-6

: Do you remember this junction?

Degree	Surely remember	slightly remember	either remember/ neither remember	hardly remember	not remembering at all
	1	2	3	4	5
Junction-1					

 How do you describe this junction? Indicate the reasons helping you to remember this junction? (e.g. any building or view from one of the street)

 **Do you remember the corners?**

Degree	Surely remember	slightly remember	either remember/ neither remember	hardly remember	not remembering at all
	1	2	3	4	5
Corner-1					
Corner-2					
Corner-3					

 What features of the corner help you to remember it? (Size, material, colour, function, context of the building…)

 **Do you remember this view?**

Degree	Surely remember	slightly remember	either remember/ neither remember	hardly remember	not remembering at all
	1	2	3	4	5
View-1					
View-2					
View-3					

Junction-7:

Do you remember this junction?

Degree	Surely remember	slightly remember	either remember/ neither remember	hardly remember	not remembering at all
	1	2	3	4	5
Junction-1					

How do you describe this junction? Indicate the reasons helping you to remember this junction? (e.g. any building or view from one of the street)

Do you remember the corners?

Degree	Surely remember	slightly remember	either remember/ neither remember	hardly remember	not remembering at all
	1	2	3	4	5
Corner-1					
Corner-2					
Corner-3					
Corner-4					

What features of the corner help you to remember it? (Size, material, colour, function, context of the building…)

Do you remember this view?

Degree	Surely remember	slightly remember	either remember/ neither remember	hardly remember	not remembering at all
	1	2	3	4	5
View-1					
View-2					
View-3					
View-4					

1-3-Streets

This part examines your ability to remember the streets. Below are some of the streets from the area.

Street-1

 **Do you remember this street?**

Degree	Surely remember	slightly remember	either remember/ neither remember	hardly remember	not remembering at all
	1	2	3	4	5
Street-1					

What features of this street help you to remember it? (any particular building, material, colour, the character of the street,…)

Street-2

Degree	Surely remember	slightly remember	either remember/ neither remember	hardly remember	not remembering at all
	1	2	3	4	5
Street-2					

 What features of this street help you to remember it? (any particular building, material, colour, the character of the street,…)

Street-3

Degree	Surely remember	slightly remember	either remember/ neither remember	hardly remember	not remembering at all
	1	2	3	4	5
Street-3					

What features of this street help you to remember it? (any particular building, material, colour, the character of the street,…)

Street-4

Degree	Surely remember	slightly remember	either remember/ neither remember	hardly remember	not remembering at all
	1	2	3	4	5
Street-4					

What features of this street help you to remember it? (any particular building, material, colour, the character of the street,…)

Street-5

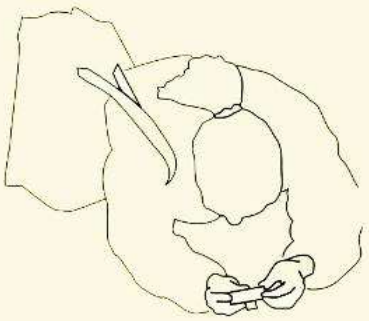
Degree	Surely remember	slightly remember	either remember/ neither remember	hardly remember	not remembering at all
	1	2	3	4	5
Street-5					

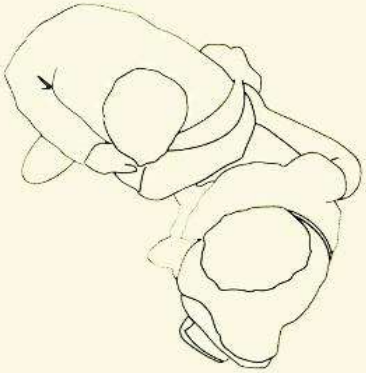
What features of this street help you to remember it? (any particular building, material, colour, the character of the street,…)

Street-6

Degree	Surely remember	slightly remember	either remember/ neither remember	hardly remember	not remembering at all
	1	2	3	4	5
Street-6					

What features of this street help you to remember it? (any particular building, material, colour, the character of the street,…)





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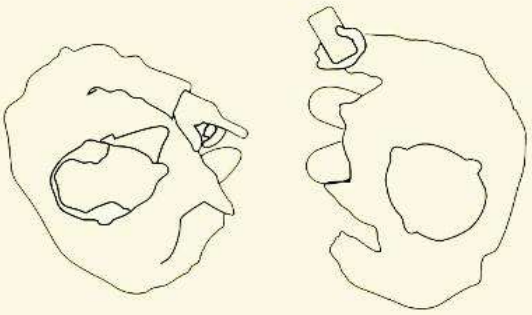

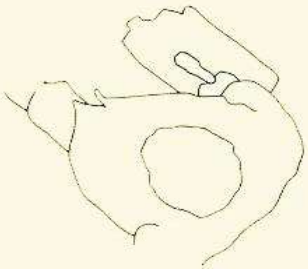

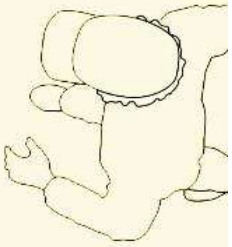

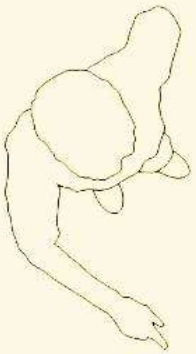

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