MASTER

Navigating through an unfamiliar environment

the difference in spatial knowledge acquisition between using a paper map and an electronic navigation device

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PREFACE

Within my master Design and Decision Support Systems at the Urban Planning Group of the Faculty of Architecture, Building and Planning from Eindhoven, University of Technology, I have focused on three topics while choosing projects and courses. These topics are research methodologies, urban planning and environmental psychology and in this thesis all three are represented.

Wayfinding and navigating have never been one of my stronger personal qualities; I am quite likely to forget how to reach a destination unless the focus is really on remembering it. However, this doesn't make the matter any less attractive for me. It is interesting to know what factors are involved in the process of finding one's way, and what aspects might help people in acquiring spatial knowledge and developing a cognitive map.

In the spring of 2010 an orientation on the subject of navigation and spatial knowledge took place, and in the summer of that year the opportunity rose to link my research to that of a PhD Candidate; Sehnaz Cenani. She will be able to use outcomes of this report and the surplus of gathered data within her research.

At this place I would like to thank Sehnaz, as well as the other members of my committee, Aloys Borgers and Astrid Kemperman, for their feedback, help and many hours of useful meetings. Furthermore I would like to thank Peter van der Waerden for his assistance with setting up the internet survey, and also all participants in the study who ensured that there were data to be analysed. I am also grateful for the owners of tobacco shop 'Postiljon' and café 'de Strijpse Ketel' who offered me a warm place to stay during the experiment, while waiting for the next participant.

All in all, I am very pleased with the report lying here in front of you. During the (mostly solitary) process leading to this result I received support from so many -and in particular from Stan and my family- which made that I stayed on track and enjoyed working on this thesis.

Nienke Wielens

July, 2011

SUMMARY

This study is about people, their surroundings, their movements in this setting, and the knowledge they acquire while doing so. More specifically, it is about navigating through an unfamiliar urban environment while using either a paper map or an electronic navigation device for guidance. Of interest are the differences that exist in the type and amount of spatial knowledge that has been acquired during navigation.

The model in figure 0.1 summarises the field of interest for this study. Information about the environment we experience is decoded via mental processes and stored in the brain of individuals. The lay-out of an environment has an influence on the type and amount of information that is stored, but maybe even more important are the mental processes involved. These processes of perception, cognition and cognitive mapping are different for each person due to personal characteristics, and the stored spatial knowledge in a cognitive map. Spatial knowledge can be divided in three stages; landmark (lowest stage), route, and survey (highest stage) knowledge, each with their own characteristics.

Navigation aids that people use can help them with wayfinding and navigation, but can also have an effect on the mental processes in their brain. As a result of that, the perception of the environment and the amount of stored spatial knowledge in the brain of the individual may change. The most important distinctions that can be made between navigation aids concern type; exocentric or egocentric, and method of display; electronic or printed.

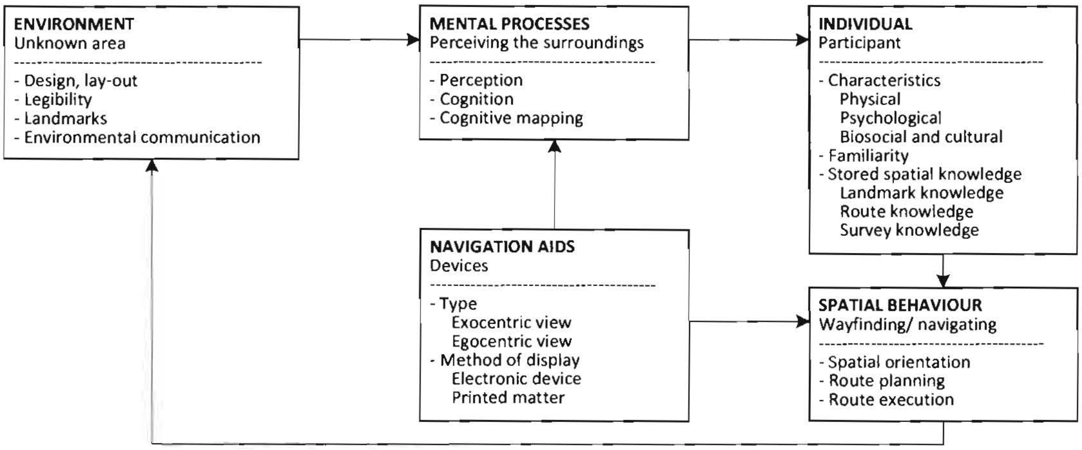


Figure 0.1 Conceptual model illustrating the relations between all important terms in this study.

To measure the effect of different navigation aids on spatial knowledge acquisition while walking through an unfamiliar environment, an experiment is designed and performed. Two neighbourhoods in the city of Eindhoven are used for the data collection. Sixty students following the course Urban Plans participated in the study, and they are divided over four experiment groups. Per experiment location there are two groups; a paper map group using a 2D north-up map with the entire route visible at one moment, and an electronic navigation device group with a 2D head-up map where at one moment only a small part of the route is visible.

The experiment is divided into four parts, the first part being an internet questionnaire with general questions, an availability check and a first administration of the Santa Barbara Sense of Direction (SBSoD) self scale test. The second part of the experiment is the actual walking of the route and directly afterwards a direction pointing task where the participant indicates directions towards three locations seen en route. The third and fourth parts are identical questionnaires which contain several tasks measuring spatial knowledge. The fourth part is administered one week after part three and is included to investigate the decay of spatial knowledge over time. The hypothesis is that paper map users will perform better on the different tasks than electronic device users.

The questionnaire used in the third and fourth part consists of seven tasks, the first four being recollection and the last three being recognition tasks:

- Sketch map drawing (measuring landmark, route, and survey knowledge);
- Giving navigation directions (landmark and route);
- Drawing the walked route on a map (route);
- Marking striking features on a map with the correct route indicated (landmark and survey);
- Landmark and intersection recognition from photographs; including certainty questions (landmark);
- Ordering photographs of intersections in the right sequence (route);
- Placing photographs of intersections on a map; including certainty questions (route and survey);

These tasks are followed by another administration of the SBSoD test.

Analysis of the gathered data has lead to results for the route drawing and photograph ordering tasks, both measuring route knowledge. For both tasks, map users performed significantly better than device users, thus supporting the hypothesis.

It might be the case that participants acquired too much spatial knowledge to make a difference in landmark knowledge tasks, and too little for survey knowledge tasks. This may explain why on the tasks measuring route knowledge (with route knowledge standing in the middle between landmark and survey knowledge) the significant differences between paper map and electronic device users were found.

Certainty scores are found to correlate with the performance on the corresponding tasks, indicating that when the participant was more sure about his answer, he also scored better on the task. Furthermore are correlations found between certainty scores and both administrations of the SBSoD tests. This indicates that a higher sense of direction leads to more confidence on performing spatial tasks.

Recommendations that can be given to developers of electronic navigation devices are firstly to give the participant a good overview of the environment, which can stimulate the development of a cognitive map and higher stages of spatial knowledge. Furthermore it is important to keep the user engaged in the navigation process, since when many mental processes are eliminated, the development and acquisition of spatial knowledge is stagnated.

TABLE OF CONTENTS

APPENDICES (in separate booklet)

A	Communication with participants
B	Internet survey
C	Santa Barbara Sense of Direction self scale test
D	Study area
E	Questionnaire and answer sheets
F	Photographs for orientation and recognition tasks
G	Correct solutions to tasks
H	Codebook
I	Answers

1

INTRODUCTION

1 INTRODUCTION

Many people will remember a moment when after travelling with an electronic navigation device, such as for example a TomTom or a Garmin, they can not remember how they got at their destination. Just blindly following directions from the device has led you there, but there is no way you can find your way back without using it again. You might feel kind of disoriented and helpless. What to do when software fails, batteries run low or some emergency happens? And what if you want to go to the same location again next time? You are obliged to use a navigation device again, even though you have travelled the same route before.

Up until now this scenario has especially been recognisable and relevant while driving a car or other motorised vehicle. However, with the introduction of electronic cartographic maps and navigational functions on devices such as smartphones, more and more people are experiencing the same while walking and using their device for navigation.

This present graduate study is about how those electronic navigation devices have an influence on the way humans experience their surroundings, what they remember from this environment, and how this information is stored in their brains.

The following section gives a brief overview of these concepts and their relations to each other. Next, the research question and sub questions for the study are put out and finally it is mentioned how the report is structured.

1.1 Conceptual model

The subject area of this study can be summarised with the conceptual model shown in figure 1.1. The diagram is deducted from the literature review as documented in chapter 2 of this report. At this position the model already gives a preview of what is to come and at the same time it introduces some terms which will make it easier to understand the research question as stated in section 1.2.

Put shortly, the model is about how we perceive the environment around us, how we behave in this environment, and how both these actions can be influenced by the use of navigation aids. We observe and perceive the environment which surrounds us via mental processes, and this spatial knowledge can be stored in our brain (arrow 1 & 2). Besides this actual experience our process of knowledge acquisition might be influenced by the use of for example a map, a device, or directions someone gives us (arrow 4). These navigation aids may also influence our behaviour (arrow 5) after we have decided to take a certain route or go some direction (arrow 3) by for example suggesting other routes. And then to complete the circle, the way we act can change the environment, disregarding the fact that there need to be enough people demonstrating behaviour that does not fit in the environment, before it changes (arrow 6).

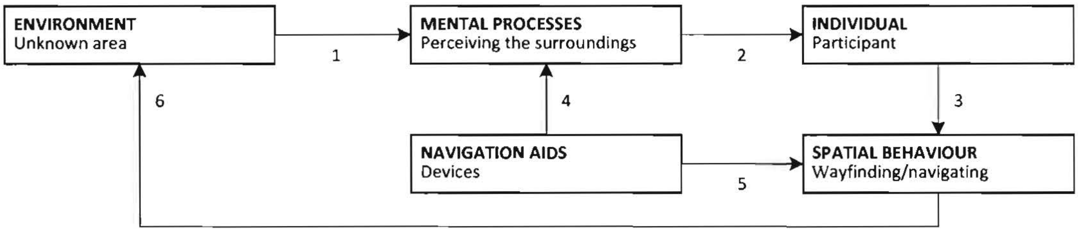


Figure 1.1 Conceptual model illustrating the relations between the main concepts in this report.

All measurements in this study are done at the level of the individual. Of interest is the amount and type of knowledge this individual has of the environment, and how this might be influenced by the use of different types of navigation aids.

1.2 Research question

The objective of this study is to investigate the amount of spatial knowledge an individual has acquired after navigating through an unfamiliar setting. Of main interest is the effect of using different navigation aids while doing so. In this case there is chosen to make a distinction between a printed map and a mobile map on an electronic navigation device. The former can be seen as 'old-fashioned', and a type of aid that many people are familiar with, while the latter is a new and upcoming type of guidance. This old/new distinction makes it interesting to investigate the difference between the two regarding the amount of spatial knowledge that is acquired after using them in a specific environment. This leads to the following research question:

> *What is the difference in spatial knowledge acquisition between using a paper map and an electronic navigation device while navigating through an unfamiliar environment?*

To be able to answer this question, a series of partial research questions has been listed, which cover its different aspects:

1. *How do people find their way?*
2. *How do people perceive their environment?*
3. *What is spatial knowledge?*

4. *How do people store spatial knowledge?*
5. *How can spatial knowledge be measured?*
6. *What are the characteristics of different types of navigation aids?*
7. *How can the influence of navigation aids on spatial knowledge acquisition be measured?*

Besides measuring the influence of different navigation aids on spatial knowledge acquisition, it is also interesting to investigate what effects the amount of landmarks present in the environment may have:

8. *What is the effect of having more or less landmarks in an environment on spatial knowledge acquisition?*

To answer these questions it is needed to get an insight in the information available about the research area and different aspects mentioned in the questions. The scheme in figure 1.1 has given a short overview, and in chapter 2 the different terms will be fully explained.

Findings can be useful in two ways. First and most important, it makes us understand how much and in which way people remember spatial information about a setting they have visited only once. Findings and results can be added to the existing theoretical knowledge. Secondly, recommendations can be made to improve electronic navigation aids so that besides reaching your destination, you also know how you got there.

1.3 Structure of the report

In chapter 2 an exploration will be made through existing literature. Existing theories and studies will be covered to get an insight in the field of navigation and spatial knowledge acquisition. The terms from the conceptual schema in figure 1.1 will serve a guideline for this.

Guided by conclusions from chapter 2, chapter 3 will describe the approach and implementation of the performed experiment. All aspects of the experiment such as location, experiment groups and the questionnaire are explained in this chapter.

Performed analyses on gathered data and the results of these can be found in chapter 4. The last chapter, chapter 5, is reserved for conclusions and a discussion of results.

2

LITERATURE

2 LITERATURE

Humans, like every other species, move through and act in the world to fulfil their needs. Depending on the purpose of moving around one pays more or less attention to what he sees and experiences in his surroundings. Maybe he knows the way, maybe he has never been there before. He might use prior experiences of this environment or a similar one; or the directional signs that lead him to his destination. So by using the brain, in combination with interpreting signals from the environment, we are able to find our way.

About the process of gathering and storing information in the brain, as well as on route choice and implications of travel behaviour, a large body of literature and research exists. In this chapter the general principles will be explained and put in perspective.

2.1 Environmental psychology

The way humans behave is for a large part influenced by the environment they are in. Think about how differently you would act at either an outdoor or an indoor location. But this is only a very first division since environments can consist of any gradation of for example a natural, built, social, educational or cultural setting; such as a park, a concert hall, a restaurant, a city centre or your own living room.

Since the 1960s there has been a rising interest among psychologists for the influence of the environment on human behaviour. Researchers realised that individuals acquire information about the environment and act in a certain way because of that setting. This was the foundation for the information-processing approach in cognitive psychology, as described in the next section (Bell et al., 2001; Gärling & Golledge, 1993). In section 2.1.2 perception and cognition –or in other words the way we take in the world around us– are explained. The mental construct where all this (spatial) information is stored is called a cognitive map, as put out in section 2.1.3.

2.1.1 Man-environment relationships

In our daily lives two different environments exist. These are a physical, tangible environment, and a cognitive environment, which can be seen as a constructed image in the brain. Both the interaction between the physical environment (*environmental structure*) and cognitive environment (*interface*, the brain), and the influence it has on spatial behaviour has been illustrated by Golledge and Stimson (1987), as seen in figure 2.1.

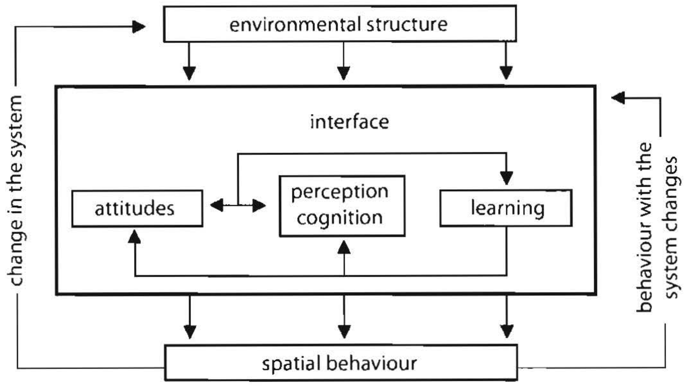


Figure 2.1 The Man-Environment Behavioural Interface (Golledge & Stimson, 1987, p.11).

The diagram in figure 2.1 shows how the behaviour of people is influenced by the *environmental structure* and reversely how this structure can be influenced by *spatial behaviour* people show. The physical environment has an effect on people, represented by the *interface* in the diagram. These stimuli are being processed by the brain, through perception and cognition, and make up a certain attitude. This attitude or choice leads to spatial behaviour, which takes place and fits in the physical environment. However, when many people demonstrate behaviour unconformable with the physical environment, this may lead to an adaptation of the environmental structure. This can be as easy as planting some flowers in communal ground because you think it looks nice in front of your house, or as large as a municipality redesigning a square that doesn't have enough room for the weekly market that takes place.

The diagram also shows the *cognitive mapping process*, which is located in the behavioural interface. Past and present environmental experiences are organised and given meaning, or as Golledge and Stimson (1987, p.11) say; it is the "black-box within which humans form the image of their world" (see also section 2.1.3).

2.1.2 Perception and Cognition

Being human, we observe and take in the world around us, as visualised in figure 2.1. This real world is very complex and sending out indefinite amounts of information signals. Because of this complexity we can only pick up a small portion of the information that is sent out. Individuals receive the signals through their senses; sight, hearing, smell, touch and taste. A strong stimulus may be impounding on the brain, but in general the sensory system decides what to look for. The senses only record those stimuli that are of direct interest for a person at that moment, and ignore the rest. This process of selection is called *perception*.

Cognition stands for how the received stimuli are stored and organised in the brain. The information acquired is added to that what was already there. In the future, this information can be used again, for example to find your way home or to give directions to a passerby who is unfamiliar to the setting (Golledge and Stimson, 1987).

When information signals are filtered through perception and further filtered through cognitive structures of previous experiences, a *mental image* of the objective environment is formed. This process is visualised by Golledge and Stimson (1987) in figure 2.2.

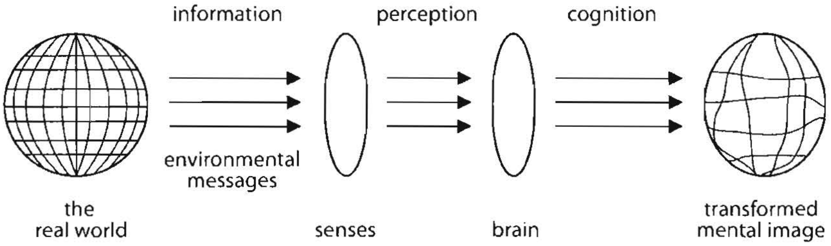


Figure 2.2 The formation of images (Golledge & Stimson, 1987, p.37).

Both the mental image an individual has and the behaviour this individual shows in a certain environment are different between people. This can firstly be explained by the different selections the senses make in perceiving the world, as well as different interpretations made by the brain and the way this is recalled later. Secondly, the specific condition of the environment at the moment it is perceived can have an influence on how and what is remembered. Think about the time of day, different seasons and also the viewpoint you have (Lynch, 1960).

2.1.3 *Mental images, cognitive maps and cognitive mapping*

In 1960, Kevin Lynch wrote his pioneering book *The Image of the City*. As the title suggests Lynch writes about the mental image a person develops in the brain, but it is also about how this image can be translated into words, diagrams, and maps. He both describes the study he performed in three large American cities and his theory leading up to and derived from this. The following citation shows his fascination with the city itself and the way people experience it (Lynch, 1960, p.1):

"Looking at cities can give a special pleasure, however commonplace the sight may be. Like a piece of architecture, the city is a construction in space, but one of a vast scale, a thing perceived only in the course of long spans of time. [...] At every instant, there is more than the eye can see, more than the ear can hear, a setting or a view waiting to be explored. Nothing is experienced by itself, but always in relation to its surroundings, the sequences of events leading up to it, the memory of past experiences."

What Lynch (1960) in his book calls the *image*, is in general called a *mental map* or *cognitive map* by researchers in the field of environmental psychology. In 1948 Edward Tolman was the first to use the term cognitive map, in his study of the behaviour of rats in a maze. He found that rats learn about the spatial lay-out of the maze, and therefore must have developed some sort of map in the brain, which he called a cognitive map (Bell et al., 2001; Kitchin, 1994). In the years to follow the expression, and the concept it stands for, has been used, studied and discussed in several disciplines; besides environmental and cognitive psychologists, also geographers, anthropologists and planners have studied the matter of cognitive maps (Bell et al., 2001). Since the 1990s several developments have been the cause for a renewed interest in interdisciplinary research. The most important one among those is the development of several kinds of spatial technologies such as geographic information systems (GIS), navigation systems and smart-phones (Kitchin, 2000).

But what is a cognitive map? Is it anything like the map on paper you use to look up an address? Stea and Blaut (1973, p. 227) describe a cognitive map as a means to "predict the environment which is too large to be perceived at once, and to establish a matrix of environmental experience into which a new experience can be integrated". This definition again shows that a cognitive map is not a fixed outcome of a process, but an evolving construct which adapts to acquired knowledge and experience. So, the term map is more like a metaphor than an actual map, it is the way our spatial knowledge is stored.

A cognitive map is produced by a process called *cognitive mapping*. As mentioned before, cognitive mapping can be described as a process which takes place in the brain (Golledge & Stimson, 1987). Downs and Stea (1977, p.6) make a clear distinction between this *cognitive mapping* and on the other hand *cognitive maps*. They state that cognitive mapping is "an abstraction covering those cognitive or mental abilities that enable us to collect, organise, store, recall, and manipulate information about the spatial environment", whereas a cognitive map is "a person's organised representation of some part of the spatial environment". In other words, cognitive mapping refers to an activity; a process of doing, and a cognitive map is a product representing the world at a certain instant in time.

A researcher who recognises the difficulties in terminology has suggested using a different term for cognitive maps. Tversky (1993) introduces the term cognitive collage -which contains figures, partial information, and differing perspectives- without being map-like. While being an interesting thought, in the remainder of this report the term cognitive map will be used to describe a person's spatial knowledge he has stored in the brain. In section 2.4 about learning new environments the process of cognitive mapping will be further explored.

2.2 Finding your way

Before worrying about how we get from A to B, it is good to consider that there is a process involved with knowing where you are at some instant in time. This is a process of devising an adequate cognitive map of a setting and at the same time being able to situate oneself within that representation; it is called *spatial orientation* (Passini, 1984). We are oriented when we know where we are now, and when we know how to tie this location to a series of other locations. When orientation fails it can be said that we are lost. This is when we are unable to make the necessary link between what we see around us and our cognitive map (Downs & Stea, 1977). A feeling of being lost can especially be the case when you are in a setting which you are not familiar with or of which you have not formed an adequate cognitive map yet. Besides maybe blaming yourself for not finding your destination, having trouble finding one's way could lead to certain other negative effects (Arthur & Passini, 1992):

- Frustration and stress: Being lost makes people insecure and afraid. On the other hand excitement and satisfaction can be felt when solving a wayfinding problem.
- Safety: In an emergency situation such as a fire, wayfinding could be a case of life and death, and not being able to find your way may give a feeling of fear. Safety issues might be more relevant for a building than for a large-scale environment, but it can be said that a setting is safer if it is well understood by the users and if they can easily get around in it.
- Decreased accessibility: A confusing or hard to reach environment is not attractive to visit again. This could especially be the case for handicapped or elderly people who have difficulty walking.

In the following section it is explained how we find our way and what we need to do so. Next, in section 2.2.2, the term navigation is introduced as a specialisation of this wayfinding.

2.2.1 *Wayfinding*

Finding our way -when travelling from A to B- is something we do many times a day, and it is a much more pleasant experience than being lost. You probably know exactly how to get from your home to work or school, or to a supermarket nearby. However, finding a friend's house in a neighbourhood you don't visit regularly may prove to be a more difficult task. In general we can say that the more frequently you travel a certain route, the more familiar you get with it.

As explained before, remembering and learning the spatial layout of an environment is a cognitive process, called cognitive mapping, and this is required for the process of wayfinding. Wayfinding describes the process of reaching a destination -either familiar or unfamiliar- and is defined by Passini (1984) as a spatial problem solving process, consisting of three distinct abilities, which do not necessarily take place in this order (Passini, 1984):

- A cognitive mapping or information generating ability that allows us to understand the world around us;
- A decision making ability that allows us to plan actions and to structure them into an overall plan;
- A decision executing ability that transforms decisions into behavioural actions.

Golledge (1999) also describes wayfinding as a purposive, directed and motivated activity; it is the process of determining and following a path or route from an origin to a specific destination (Golledge, 1999). In this definition we recognise the two last abilities noted by Passini.

2.2.2 *Navigation*

It is becoming more common to differentiate between wayfinding and a concept very much related to that: *navigation*. Wayfinding is taken more generally to involve the process of finding a path between an origin and a destination, that has not necessarily previously been visited. On the other hand implies navigation that the route to be followed is predetermined, deliberately calculated, and defines a course to be followed between a specific origin and destination. So it can be said that navigation is more than wayfinding concerned with criteria such as shortest time, shortest path, minimum costs and least effort. For navigation, a traveller usually has to plan a route before travelling whereas wayfinding is more exploratory or adventurous; a traveller can make decisions during the travel process depending on emotion or satisfaction (Golledge & Gärling, 2002).

Another approach is described by Daniel Montello (2005), who classifies navigation as an act which consists of two components; *locomotion* and wayfinding. Montello explains locomotion as the movement of one's body in an environment, coordinated specifically to the local or proximal surroundings; it is really about finding a place to set your feet and avoiding obstacles. Wayfinding on the other hand is the goal-directed and planned movement of one's body around an environment in an efficient way; it requires a destination we wish to reach. For wayfinding, memory –both stored in the brain and in objects such as maps– is crucial, since most of the time the destination is not in the local surroundings and we have to choose routes and create shortcuts (Montello, 2005).

It can be said that both Golledge and Gärling (2002) and Montello (2005) see navigation as a specialisation of wayfinding. The former emphasise on the planning aspect being involved, while the latter also incorporates the notion of locomotion.

2.3 The physical environment and the individual in it

How we perceive and process the information sent out by the environment has a great deal to do with our brain, as described before. Some people may be fast in forming an elaborate cognitive map because of past experiences, while others have more trouble to do so. This is not solely due to the differences in our systems, but also has a great deal to do with the *legibility* of an urban structure. Legibility is explained by Lynch (1960, pp.2-3) as the "ease with which parts of the cityscape can be recognised and can be organised into a coherent pattern. [...], so a legible city would be one whose districts or landmarks or pathways are easily identifiable and are easily grouped into an over-all pattern".

The perceived legibility of a (part of the) city influences the rate of which an environment is learned. When the environmental information is incorporated into a cognitive map we can speak of *imageability* (Golledge & Gärling, 2002; Lynch, 1960). Besides legibility and imageability there are other aspects of the environment –and the person in it– that influence the speed of learning and how much is remembered, as we will see in the following sections about landmarks, environmental communication and aspects of the individual.

2.3.1 Landmarks

Each environment has features standing out from their background. This can be seen on all levels ranging from for example 'must visit' places noted in a tourist guide to a neighbour's brightly coloured front door where the standard is white (see figure 2.3). There are several components of the real world that influence what elements will be incorporated in a person's cognitive map. According to Lynch there are three, which always appear together (Lynch, 1960):

- Identity: the identification of an object and how distinct it is from other objects, its individuality;
- Relation: the object has a spatial or pattern relation to other nearby objects, there is for example variation in setback, height or scale;
- Meaning: the object has meaning for the observer, either practical or emotional.

Figure 2.3 Landmarks exist on different levels.
Left: Florence tourist map (mappery.com). Right: a front door in a distinctive colour.

The objects standing out from their surroundings are called *landmarks*. Landmarks at a decision point or along a route are called *local* landmarks, the ones further away that are used for overall guidance are called *distant* landmarks (Lynch, 1960).

What one person considers to be a landmark, may not be one for someone else. A specific house can for example be a landmark along your route because you know the person living there, but it may not be for another who doesn't know the occupant. What makes an object into a landmark is therefore a relative property; it depends on both the characteristics of the individual as on how much the object stands out from its surroundings (Gärling & Golledge, 1992; Klippel & Winter, 2005). In section 2.4.2 about the process of learning we will see that landmarks play an important role in the development of spatial knowledge.

2.3.2 *Environmental communication*

Besides landmarks, which are generally a built structure, a distinctive part of a building or a natural element, there are other ways people are helped in understanding and moving through an (large-scale) environment. These tools are two types of graphical information; *signs* and *cartographic maps* (Arthur & Passini, 1992).

Signs can have a variety of functions, but all types communicate environmental information. Most signs are directional, which means they tell the viewer what is where and how to get there. Typically these signs designate a place, an object or event in the form of a name of symbol accompanied with an arrow. Figure 2.4 shows a directional sign at Schiphol Airport designed by Paul Mijksenaar; without it the airport would be a labyrinth.

Figure 2.4 Signs. Left: Directional sign at Schiphol Airport (mijksenaar.nl).
Right: A reassurance sign along the highway in Australia (freewebs.com).

A second type of signs is the identification sign; it states a description of location. They identify an object or a place, it is for example the number that classifies the floor you are on or the letter '*i*' above an information desk. The third function for a sign can be to give reassurance, as some sort of checkpoint. So they are not used in the wayfinding process, but in the post-decision phase (Passini, 1984).

Cartographic maps represent a part of an environment. By making them, selections are made regarding several aspects. First of all, it is important to decide for whom the map is primarily made, and for what purpose. Is the map intended for pedestrians or drivers, for sightseeing or everyday living, for strangers or for those already familiar with a city? Secondly are of importance the perspective –usually vertical or 'bird-eye'– and scale. Scale is important because it determines the trade-off between the amount of detail that is shown, and how much of an area can be included in the map. Furthermore, decisions about usage of symbols and colours need to be made. Both the choice of scale and symbols have a great deal to do with whom the map is for and what they need to know. Cartographic maps can have many different appearances and include for example true-to-scale architectural drawings, schematic maps of the underground, fantasy drawings of a theme park or an axonometric view of the city centre. Some maps are used in a specific profession –e.g. by geographers, urban planners, or municipal officials–, others are distributed among visitors to a location. Maps may be consulted on the internet, they can be printed, and some are mounted on a pole or wall as a 'you-are-here' sign (Downs & Stea, 1977; Passini, 1984; Porathe, 2008).

Both signs and maps can help individuals during their cognitive mapping and navigation processes. When designed well and especially when used by the audience that it was designed for, they help us in understanding and moving through our surroundings.

2.3.3 The individual

Not everybody needs the same amount of information to find their way from A to B. In section 2.1.2 about perception and cognition it is already mentioned that people selectively pick up stimuli from the environment, and may also store this information in different ways. Depending on for example experience, how eager you are to learn, the time available, choice of transportation mode or because some people need more information than others, a wayfinding situation is different for every person. Characteristics of individuals can be divided into three groups (Arthur & Passini, 1992; Liben, 1981):

- Physical: age (e.g. eye-level and speed of motion) accounts for many differences in perceiving and acting in an environment. In addition, physical and sensory handicaps can have a great impact.
- Psychological: emotions, feelings and mood determine the relation between the individual and the environment at a certain moment. The familiarity with a location and also the self-perceived spatial abilities a person has are supposed to affect performance on space-related tasks.
- Biosocial and cultural: gender and other genetic factors such as intelligence play a role as well. The family, house and neighbourhood you grew up in, and more in general the cultural setting or values, determine in part the way you interact with your surroundings.

2.4 Learning a new environment

When unknown to a setting, or when it is the first time a journey is taken, you are confronted with a spatial problem that needs to be solved; how to get from A to B, and via which route? To solve the problem, three types of information -related to the three wayfinding abilities mentioned in 2.2.1- are needed (Arthur & Passini, 1992):

- Information to make a decision: questions like 'Where am I?', 'What do my direct surroundings look like?' and 'Where is my destination?' need to be answered.
- Information to execute the decision: information -such as landmarks, maps or signs- which leads to the destination.
- Information to conclude the action: information indicating that you have reached your destination.

In the following section, it is explained that there are different strategies that can be followed by a navigator, as well as by the researcher looking at this behaviour. Next, the process of learning and its different stages are put out.

2.4.1 How we learn

For a person moving through an environment, there are two different navigational strategies, called *primary* and *secondary learning*. Primary learning involves direct experience with the environment. You actually move along a route and by doing that knowledge of that route is acquired. Landmarks like salient buildings can serve as a basis for both route choice and route learning. Secondary learning on the other hand is studying a cartographic map or another representation of the environment, in order to learn and plan the route.

This division in types of learning is also one of the ways researchers can analyze how an individual learns a new or unfamiliar environment. They look at the resources that are used, being either direct observation (primary learning) or studying maps and other sources (secondary learning). Often it will be the case that both strategies are used by an individual, either simultaneously or at different moments in time, as also shown in figure 2.5 (Bell, 2001; Golledge, 1999; Lloyd, 1993; McDonald & Pellegrino, 1993; Thorndyke & Hayes-Roth, 1982).

Another strategy used by researchers is investigating the amount of spatial knowledge a person has stored in his cognitive map, and how this may change over time. There are several authors who describe distinguishable stages in spatial knowledge, although there are some small differences in terminology and the exact separation of stages.

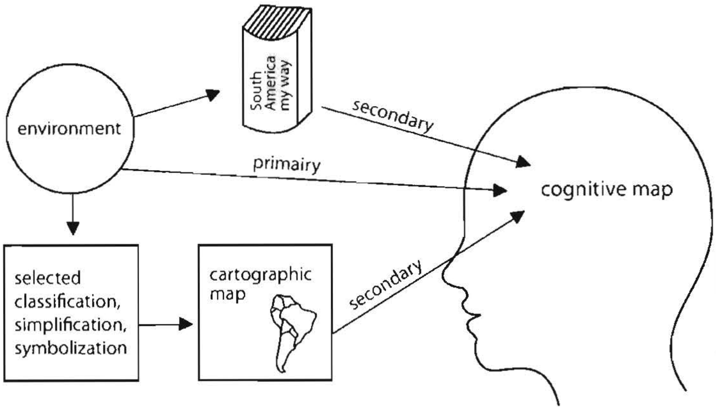


Figure 2.5 The encoding of information about the environment from primary and secondary sources (after Lloyd, 1993, p.146).

2.4.2 *The process of learning*

When a person experiences an environment more and more –e.g. because he gets older, or lives longer at a certain place– his spatial knowledge improves both quantitatively and qualitatively. The quality is mainly improved because of changes in its type of organisation. With experience three consecutive stages of spatial knowledge can be identified: the level of *landmark*, *route* and *survey* knowledge. This progression and the characteristics of spatial knowledge are clearly illustrated by Stern and Leiser (1988) as can be seen in figure 2.6.

Landmark knowledge is the most basic form of spatial knowledge. One can recognise familiar surroundings or objects –a landmark–, without per se having knowledge of that landmark's position relative to other locations; with only landmark knowledge you can not complete a trip to a new location. Sometimes the knowledge at this stage is also called declarative knowledge.

Route knowledge (or procedural knowledge) includes the order of the landmarks from one place to another, as well as direction information. It lacks however definite knowledge of the relative positions of locations. At this stage the cognitive map appears to consist of a (large) collection of routes. The routes may be purely enactive, where the travelling individual recognises where to go at an intersection but is unable to describe the entire route from memory, or the route knowledge is recallable from memory and available for say route description. For young children this type of spatial knowledge is very characteristic. Usually children do not draw their neighbourhood from a global or bird's eye perspective, but as through imagining they are walking in it (see also figure 2.7). When drawing they often turn their paper so it corresponds with the cognitive map in their head.

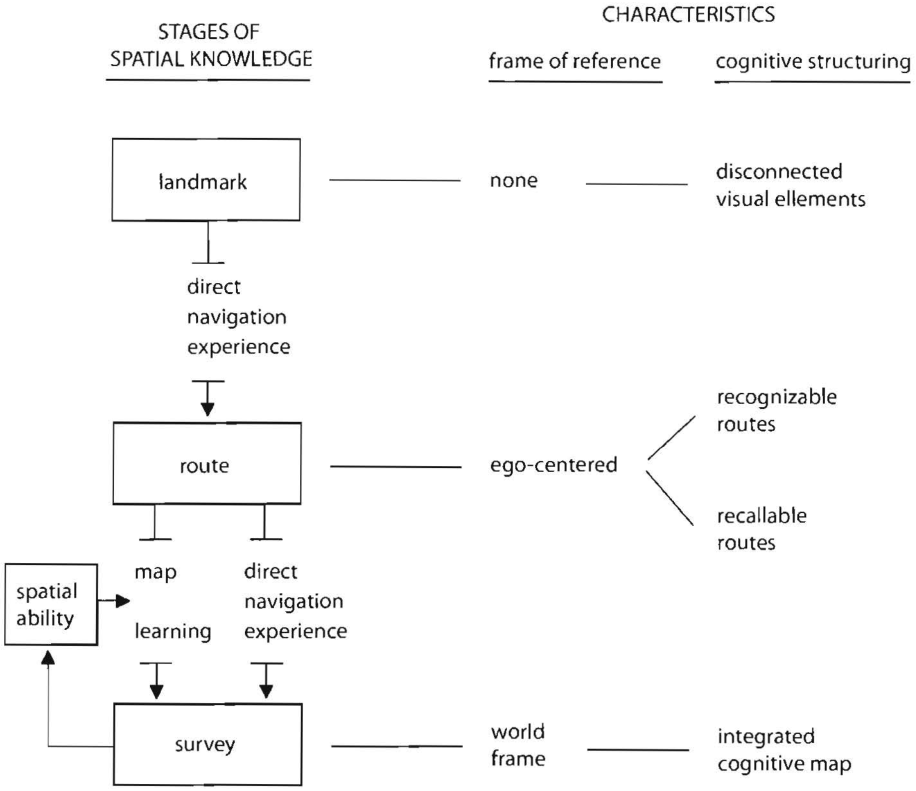


Figure 2.6 Progression and characteristics of spatial knowledge (Stern & Leiser, 1988, p.142).

Survey knowledge (or configurational knowledge) is the most advanced type of spatial knowledge. It means the individual has acquired a proper spatial understanding and in his cognitive map information about the relative locations of objects in the environment is stored. Instead of thinking about routes as ordered sequences of direction choices, he now sees them as links between locations. When possessing survey knowledge it is possible to plan routes between places which have not been visited before (Asselen et al., 2006; Appleyard, 1970; Bovy & Stern, 1990; Chown et al., 1995; Downs & Stea, 1977; Freundschuh, 1992; Golledge & Gärling, 2002; Golledge & Stimson, 1987; McDonald & Pellegrino, 1993; Siegel & White, 1975; Stern & Leiser, 1988).

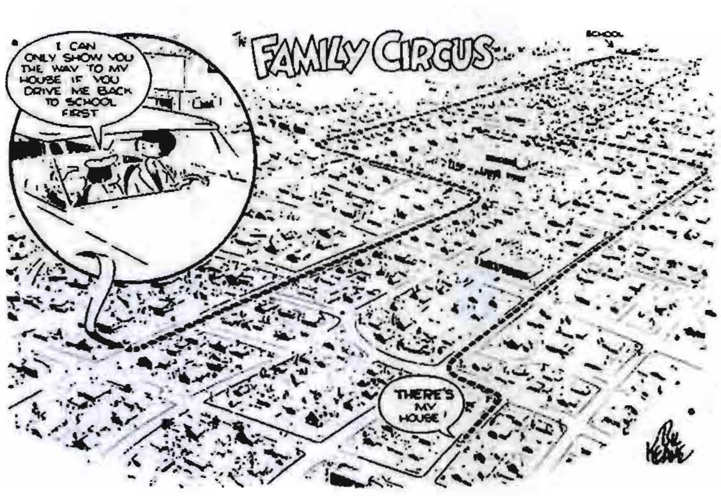


Figure 2.7 Most children possess only landmark and route knowledge (Downs & Stea, 1977, p.14).

In figure 2.8, a model of spatial knowledge is shown as made by Freundschuh in 1992. This model adds the aspect of time to the progression of spatial knowledge. It shows that the amount of spatial knowledge an individual possesses is not a static representation, but instead a dynamic representation that refines or decays over time.

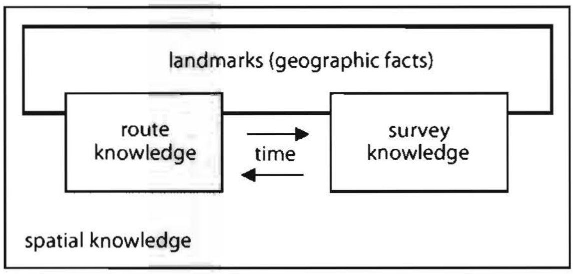


Figure 2.8 Model of spatial knowledge with the factor 'time' added (after Freundschuh, 1992, p.291).

What we have seen is that when someone has more experience with a certain environment -either directly or via other sources- the amount of spatial information in his brain grows. This information is stored in the cognitive map this person has, which can be in the form of landmark, route, and survey knowledge. When however the environment is not experienced again or on a regular basis, it is very well possible that the amount of spatial knowledge will become less over time.

2.5 Navigation aids

When planning for a trip, or while navigating through a new or unfamiliar environment, many people will use some type of navigation aid to guide them and help reaching their destination. In section 2.3.2 some aspects of directional signs and cartographic maps have been described; in the following sections a closer look will be taken at the different types of maps and other navigation aids, and the ways information can be displayed and transferred to the individual. In section 2.5.3 drawbacks that electronic navigation devices may give when using them are put out.

2.5.1 Type

In his paper called 'Measuring effective map design for route guidance' Porathe (2008) describes a laboratory experiment where people navigate in a grid while using different displays of electronic maps. In general, he distinguishes between two types of maps; the *exocentric* and *egocentric* view (see figure 2.9).

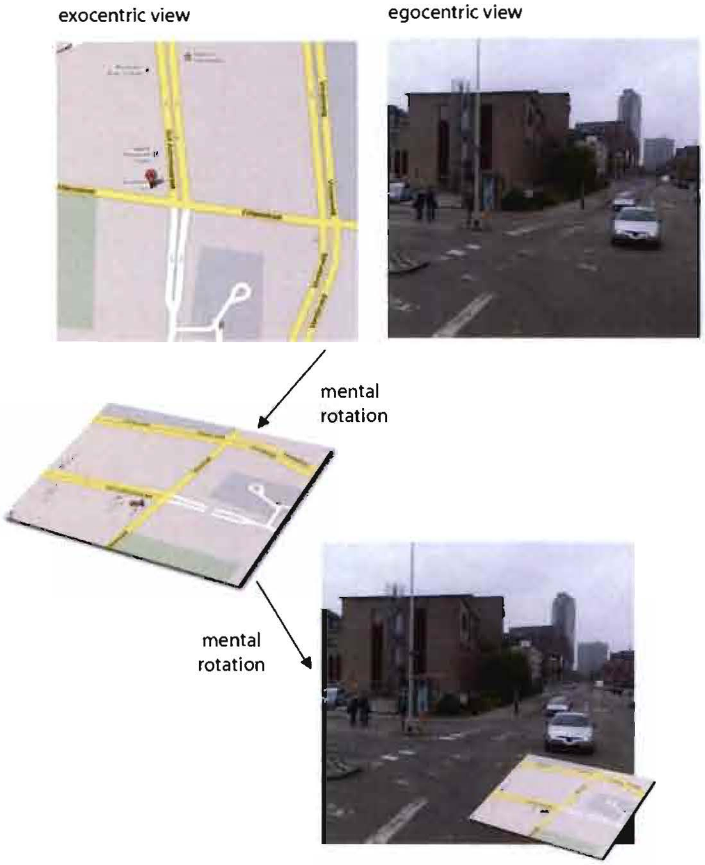


Figure 2.9 A typical exocentric wayfinding device is a paper map, while the egocentric view can be compared with directions someone gives to you (after Porathe, 2008).

The egocentric view is movement based and is a natural view for humans because it is the way we experience and navigate through our surroundings. It is like when someone for example gives you directions on how to reach a specific destination. Another example is the 3D mode which is available on many electronic navigation devices. The information you get from or about the environment is only valid for a certain route and in a certain direction (think about the child in figure 2.7).

The exocentric view on the other hand is a synthetic view, which does not come naturally to us and has to be learned. This view can be seen as a bird-eyes perspective, which makes it possible to integrate routes. However, to be able to act on it we have to transform the exocentric view with several *mental rotations* to egocentric.

Cartographic maps present the world in an exocentric view, where the navigator has to imagine himself hovering in the air. Most modern maps are oriented on the North. So when having a map in front of you with the north on the top, it can be said that this map is in a *north-up* position. However, when using a map to navigate, a large majority of people finds it more easy to use when the top direction of the map is the facing (heading) direction; the *head-up* or *forward-up* position. This is why the 'navigator' in the passenger seat of a car or any other person who tries to find his way frequently turns the road map when a turn is made (Montello, 2005; Porathe, 2008).

2.5.2 Method of display

The most traditional of present-day navigation aids, besides of course verbal instructions, is a cartographic map in the form of *printed matter*. Think for example about hand held maps such as a Falkplan, a tourist map or even a print from the internet. As said before, these are usually north-up. Typically all or at least a large part of the route and environment is visible at one time, but there is no indication of your position.

Since the development of the computer and more recent the introductions of smartphones and *electronic devices* especially developed for assistance with GPS navigation, other ways of displaying maps have been made possible. Like the paper map they can be north-up, but more typically they are head-up or in a 3D (egocentric) mode where the image rotates and/or changes to match your position and orientation while moving forward. Usually only a small part of the route and environment is visible at the same time, partly due to display size. Since the device knows where you are on the map, most often this location is indicated. Quite often there is also the possibility to show extra information on the map, such as store or gas station locations and traffic information.

In his experiment Porathe tested the effectiveness of three different electronic map displays - north-up, head-up and a 3D mode- and a traditional hand held map. The results show that people are much faster and make fewer mistakes when using the 3D map. Also, they ranked the 3D map as being the most user-friendly (Porathe, 2008).

2.5.3 *Difficulties with automation*

Porathe's (2008) results might indicate that it is best to use a type of 3D map while navigating through the environment. This could be true when just looking at a one-time experience where origin and destination are clear, and when you can use the 3D map again to find your way back. However, often we will be coming back to a specific location at a later time, for example to shop there, to visit a friend or to go to your dentist appointment. And when coming back, it would be nice if we remembered how to get there. A user-friendly 3D map might have brought us to the location the first time, but has this mode taken the work-load away in such a way that we won't remember the route when we come for a second visit? Research shows that this might indeed be true.

Automation takes place in almost all work areas and in our daily lives, and the introduction of electronic navigation devices is one of many developments we see happening. In their study, Endsley and Kiris (1995) discuss the 'out of the loop' performance problem: a loss of manual skills and a loss of situation awareness with increased automation. Parush, Ahuvia and Erev (2007) investigated the degradation in spatial knowledge acquisition when using electronic navigation devices. They say that GPS-based systems can (Parush et al., 2007):

- Replace human perception;
- Replace human cognition;
- Eliminate the need for making wayfinding decisions.

This means that the individual looses the skill to do all that when required. It may also mean that there is a negative impact on the acquisition of spatial knowledge (Alslan et al., 2006; Burnett & Lee, 2005; Parush et al., 2007). Parush et al. (2007) found that keeping the user 'in the loop' -by position indication on request and orientation quizzes- can have a positive impact on spatial knowledge acquisition. The active engagement in the wayfinding tasks resulted in better spatial knowledge.

Burnett and Lee (2005) found strong evidence that the use of a vehicle navigation system (turn-by-turn guidance) as opposed to usage of a paper map will impact negatively on the formation of drivers' (in a driving simulator) cognitive maps. This is because drivers using the paper map are paying more active attention to the environment, and also because they could study the map for as long as they wished prior to their drive, which aided in the development of survey knowledge. In figure 2.10 the hypothesised relationship between navigation task demands and cognitive map development as published by Burnett and Lee (2005) is shown.

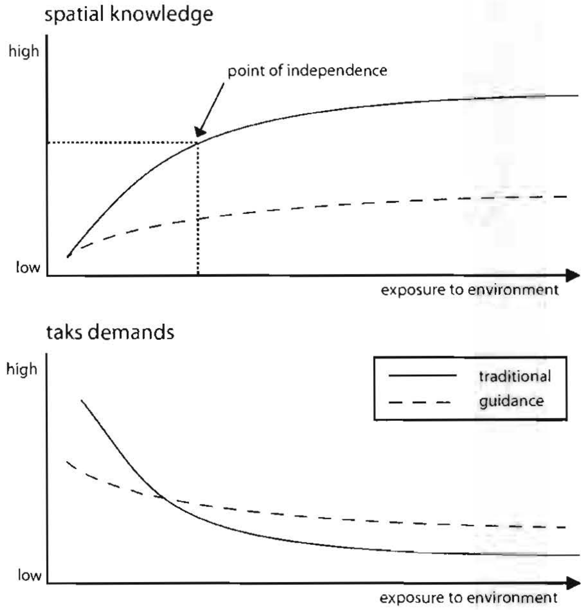


Figure 2.10 Hypothesised relationships between navigation task demands and cognitive map development (after Burnett & Lee, 2005).

The figure illustrates that with traditional methods (e.g. a map; exocentric view) the task demands are high at first, but that as exposure to the environment continues and spatial knowledge grows the demands drop strikingly. At the 'point of independence' there is no longer the need for external information. With guidance (e.g. turn by turn information or 3D mode; egocentric view) on the other hand the initial task demands are lower but -as spatial knowledge does not develop and with a constant need for external information- this will probably not reach the low levels like when using more active forms of navigation (Burtnett & Lee, 2005).

2.6 Measuring spatial knowledge: reading the cognitive map

We have seen that a person gains spatial knowledge by perception and cognition, and that as a result he forms a more or less elaborate cognitive map in his brain. However, to be able to measure spatial knowledge and perform analysis, it is necessary to 'extract' this cognitive knowledge from the person's mind. There are several different research methods to do so (Bell et al., 2001; Golledge & Stimson, 1987; Kitchin, 2000):

- Sketch maps: drawing sketches or sketch maps representing the environment, either on a base map or without any hints;
- Models: arranging toys or making models to represent the environment;
- Mapping reactions: verbal or written comments regarding the environment of which potentially a map can be constructed;
- Recognition tasks: identifying photographs or models;
- Distance and direction estimates: judging proximity and location of items in the environment.

In the following sections the for this study most relevant ways to extract and measure spatial knowledge are described.

2.6.1 Sketch maps

Sketch mapping has been proved to be a useful instrument for revealing cognitive maps. It is however important as well as difficult to interpret the maps correctly. Furthermore, the technique presumes that the person drawing understands the abstract concept of the map and that he can sketch it to some scale where information is plotted in some uniform way (Golledge & Stimson, 1987).

Kevin Lynch (1960) was one of the first to use the technique of sketch mapping to reveal cognitive maps. In addition to in-depth verbal interviews he let inhabitants of Boston, Jersey City and Los Angeles draw maps of their city. He then combined the information from all participants for both the interviews and sketch maps. This resulted in a 'public' or 'group' image; which is the overlap of the many individual cognitive maps.

The maps in figure 2.11 are made with five elements used by Lynch, and still used in analysis today; paths, edges, districts, nodes, and landmarks. As can be seen there are quite some differences between these two maps, which is the result of the way information was gathered from the participants (Lynch, 1960).

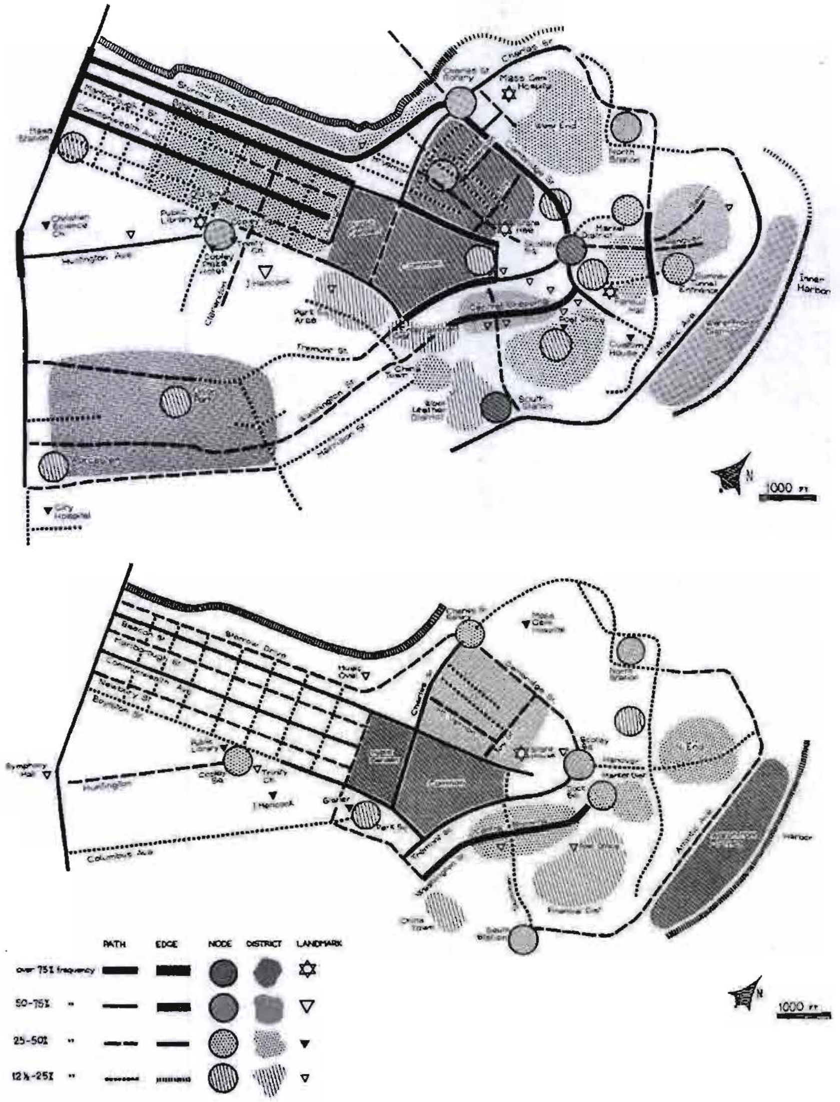


Figure 2.11 The Boston image (Lynch, 1960, p.146). Top: derived from verbal interviews. Bottom: derived from sketch maps.

In many studies measuring spatial knowledge acquisition, drawing sketch maps is one of the tasks participants have to perform after having experienced some environment (Appleyard, 1970; Asselen et al., 2006; Burnett & Lee, 2005; Devlin, 1976; Gale et al., 1990; Ishakawa et al., 2008; Lynch, 1960; Oerlemans, 2009). Usually complex scoring methods are needed to evaluate the maps. Therefore there are occasionally some clues given -such as a rough shape of the experiment area, a prominent landmark or the start/end of a route- to make analysis and comparison of the maps more feasible (Bell, 2001, Oerlemans, 2009).

Appleyard (1970) gives some examples of different types of maps people can draw. Complexity of maps can be indicated by the kind of elements present in the maps: primarily sequential elements (roads; route oriented) or spatial elements (individual buildings, landmarks and districts; survey oriented). The most developed maps will have combinations of both elements.

Burnett and Lee (2005) used in addition to this complexity classification the following characteristics of sketch maps for analysis; which can be seen as landmark, route, and survey knowledge:

- Absolute number of landmarks drawn in the map;
- Absolute number of path segments;
- The correctness of the placement of the landmarks, either in relation to other landmarks or to a path segment.

2.6.2 *Direction and distance estimations*

In several studies participants are asked to give estimations of the length of (parts of) a route, or of directions to certain locations. Usually, for length, either the shortest possible path over roads and/ or Euclidian distance (as the crow flies) are estimated. When estimating directions individuals are usually requested to point at indicated landmarks, standing at a particular location, e.g. a landmark or the start/end position of a route.

Estimating directions is really about orientation; does the person know where he is in relation to his surroundings? This also requires a form of survey knowledge or at least some integration of information; in his brain, the participant has to locate himself as well as the goal in the environment, connect them in the correct way, and than externalize this information in the way that is asked. Angles can for example be recorded with a compass or some derivative of it such as a circle on a paper with degrees marked on it (e.g. Hegarty et al., 2002; Ishakawa et al., 2008; Thorndyke & Hayes-Roth, 1982; Willis et al., 2009).

2.6.3 *Recognition tasks*

After having experienced an environment, people will be able to recognise certain features of this location shown to them on for example films or photographs. The number of items recognised, and of course the correctness of this memory, tells about the amount of spatial knowledge that is acquired.

The most basic form of recognition tasks is to recognise landmarks. A participant is shown several photographs -usually some not belonging to the experienced environment are thrown in-, and he has to indicate whether he recognises the location on it (Aslan et al., 2006; Asselen et al., 2006; Burnett & Lee, 2005; Gale et al., 1990). Another type of task is the placement of photographs of landmarks in the correct order, as how the participant saw them along his route (Asselen et al., 2006; Burnett & Lee, 2005). A third possible recognition task is about placing photographs of landmarks at their correct position in relation to each other. This can be done on either an empty area or with a simple map as guidance (Aslan et al., 2006).

Landmark recognition tasks can be seen as testing landmark knowledge, landmark ordering tasks measure route knowledge, and placing landmarks on a map involves survey knowledge as well.

2.6.4 Self report measures

In many fields of research different types of self report measures have been developed measuring moods, thoughts, attitudes and behaviour. For the present study, one self test is especially relevant - the Santa Barbara Sense of Direction scale (SBSoD)- which measures the self-perceived spatial ability of a person, as developed by Hegarty et al. (2002) (Ishikawa et al., 2008).

The scale consists of 15 questions, which have to be answered on a 7 point Likert scale. Participants respond by indicating a number from 1 (strongly agree) to 7 (strongly disagree). Questions include for example: 'I am very good at giving directions', 'I very easily get lost in a new city' and 'I enjoy reading maps'.

Besides a high test-retest reliability, Hegarty et al. (2002) showed correlation of the test with direction and distance estimation, as well as sketch map drawing. They state that the SBSoD questionnaire is that predictive of environmental spatial abilities -as opposed to tests in other fields where people often greatly overestimate their abilities- because of actual self knowledge; people exercise environmental cognitive abilities on a daily basis and they can easily think of situations where these abilities have come into play.

2.7 Conclusion

In this literature review several aspects related to the research area of the present study have been described. The conceptual model from figure 1.1 can be extended to the model in figure 2.12, where the key concepts are illustrated with the newly introduced terms.

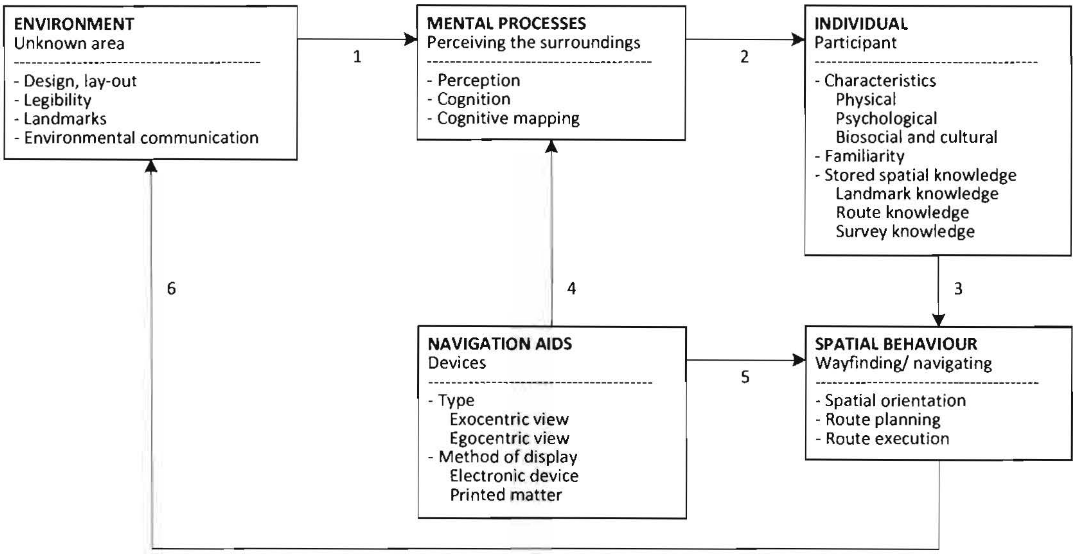


Figure 2.12 Conceptual model illustrating the relations between all important terms discussed in this chapter.

We have seen that information about the environment we experience is decoded via mental processes and stored in the brain of individuals. The lay-out of an environment has an influence on the type and amount of information that is stored, but maybe even more important are the mental processes involved. These processes of perception, cognition and cognitive mapping are different for each person due to personal characteristics, the familiarity with the environment and the already stored spatial knowledge. Navigational aids that people use can help them with wayfinding and navigation, but can also have an effect on the mental processes in their brain. As a result of that, the perception of the environment and the amount of stored spatial knowledge in the brain of the individual may change.

To be able to answer the research question; *What is the difference in spatial knowledge acquisition between using a paper map and an electronic navigation device while navigating through an unfamiliar environment?,* arrows 4 and 2 of the model concerning the effect of navigation aids and spatial knowledge acquisition, are most important.

Now we can have a look at the partial research questions stated in section 1.2 to see whether it is possible to answer those;

1. *How do people find their way?*
2. *How do people perceive their environment?*
3. *What is spatial knowledge?*
4. *How do people store spatial knowledge?*
5. *How can spatial knowledge be measured?*
6. *What are the characteristics of different types of navigation aids?*
7. *How can the influence of navigation aids on spatial knowledge acquisition be measured?*
8. *What is the effect of having more or less landmarks in an environment on spatial knowledge acquisition?*

On these questions, answers can be found in the described literature. Finding your way deals with knowing where you are, planning where you want to go, and carrying out these plans. While doing so, people perceive the environment through their senses, and knowledge concerning the spatial surroundings is stored in a cognitive map in their brain. This cognitive map may be more or less elaborate due to experience with the location, characteristics of the person, or characteristics of the environment. Landmarks play an important role in the process of knowledge acquisition, and landmark knowledge is the first stage of spatial knowledge. It can therefore be hypothesised that having more landmarks in an environment will increase your spatial knowledge. The acquired spatial knowledge can be measured by externalising the cognitive map through for example making sketch maps, pointing at directions or recognition tasks.

The most important distinctions that can be made between navigation aids concern type; exocentric or egocentric, and method of display; electronic or printed. The influence of navigation aids on spatial knowledge acquisition can be measured in an experiment by comparing the amount of spatial knowledge people have acquired of an environment, after using different kinds of navigation aids.

To be able to answer the general research question we however need to know *what* the influence is of using either a paper map or an electronic navigation device on spatial knowledge acquisition. This, and also the effect of having more or less landmarks in an environment will be investigated with an experiment, as described in the following chapter.

3

EXPERIMENT
approach & implementation

3 EXPERIMENT
approach & implementation

As seen in the previous chapter, over the last decades quite a lot of research has been done involving cognitive mapping, the process of learning an environment, and the use of different types of navigation aids. The precise subject focus and the design of these studies however make it necessary to do further research in order to answer the research question of this study.

There are however a number of studies where the present study highly relates to. Several of the measurement methods used by them are adopted, and used in a similar way. For example, Thorndyke and Hayes-Roth (1982), Gale et al. (1990), and Willis et al. (2009) all compared different ways of learning an environment. Their main focus though was on *learning* this environment. Participants experienced a certain environment a number of times, or studied it from a map (or other representation) without the actual experience. Aslan et al. (2006) and Ishakawa et al. (2008) both used some interesting techniques. Asselen et al. (2006) studied whether and to which extent spatial knowledge of a route is acquired automatically and Burnett and Lee (2005) used car drivers in a virtual environment.

For the present study it is necessary for all participants to have the same experience, measure spatial knowledge acquisition, and compare for the different aids people use while doing so.

To be able to answer the research question an experiment is performed. In the following sections the study area, experiment design and participants are discussed. Then, in section 3.4 the procedure is set out, followed by a description of the used devices and programs. All tasks and measurements performed in the experiment are explained in section 3.6.

3.1 Study area

In environmental studies, researchers have tried to find ways to represent a real environment properly with -in the early days- usage of photographs and films, and later also virtual films and virtual environments produced on computers. In quite some cases it has been shown that experiences with these virtual representations are (to some extent) comparable to experiences and reactions people give in the real world (e.g. Bell et al., 2001). The main reason why in experiments concerning for example wayfinding virtual environment are used is that these virtual environments enable researchers to have all participants experiencing the same environment. It is also possible for the experimenter to alter the environment to fit specific needs, such as control weather conditions or add specific types of buildings. Furthermore, for large studies, there are usually less costs and time involved since participants do not have to come to a (remote) location, and it is in certain cases possible to test more than one participant at one time.

Even though the quality of virtual environments has increased very rapidly since the early days, there are still quite some downsides to using them. In the first place it can be very time consuming to produce a virtual environment and most commonly there are no smells, sounds and people around. When 'walking' through a virtual environment this is usually done by use of the keyboard or a joystick, with the visuals projected in a special room or on a screen. Even if those visuals are very lifelike, it is still something quite different from a real walk in a real environment.

The use of a real environment in an experiment has some downsides as well. The situation is not completely identical for all participants since it can not be controlled by the experimenter. Even if data collection takes place over a short period of time, the weather might for example have changed, people and cars have moved about, children might be playing in the street, or maybe music sounds from an open window.

In this study, there is chosen to use a real environment. The lifelikeness of the experimental experience and external validity are the main reasons for this choice. It has been shown in studies that the actual experience of an environment as opposed to a (virtual) representation of it gives different results when measuring spatial knowledge (e.g. Thorndyke & Hayes-Roth, 1982; Willis et al., 2009). Another reason is that programming a good virtual environment as well as a navigation device to be used inside of it would be very complex.

To improve validity, it is best to use more than one environment, and in analysis compare results to see whether possible relationships found are influenced by the study area. Of course those different environments should be as comparable as possible. When choosing locations attention must be paid to the following:

- Similar residential/commercial ratio of buildings;
- Same appearance of the area's;
- Similar complexity and street pattern (and also legibility);
- Similar types of routes through the environment are possible;
- Good accessibility for participants and experimenters.

The route through the environment which the participant walks is furthermore chosen to be circular; it gives the participant the opportunity to develop a cognitive map which consists of an area rather than only a linear element.

The only way the environments should be different, is in the amount of landmarks that can be found. This difference in landmarks is needed to be able to measure possible results in spatial knowledge acquisition from having more or less landmarks. 'Amount of landmarks' is however a variable which is very hard to be measured and controlled since there are many different types of landmarks (see section 2.3.1). In the search for usable areas there is primarily looked at how different the possible routes are in terms of the buildings along side of them. When all looks very similar, and one easily shuffles streets in his mind, an area can be said to be poor of landmarks. When buildings are very outspoken and unique it can be said that there are many landmarks.

In the present study, two different locations will be used; one with more landmarks than the other. The type of environment suitable to make this distinction is a neighbourhood with primarily residential buildings, since many won't have a very distinctive character. Also, it is much more feasible –more than for example a city centre– to find residential areas that are unfamiliar to participants, which is required for the study.

For convenience there is chosen to find two neighbourhoods in the city of Eindhoven. This way the University (TU/e) is nearby, and its facilities can be used during data collection. Out of a series of options, the neighbourhoods 'Het Ven' and 'Barrier' are chosen; the first being high and the second being low in amount of landmarks. In figure 3.1 the locations of the two areas are indicated on a map of Eindhoven.

In both neighbourhoods a route has been set out, which can be found in figures 3.2 and 3.3. The routes are kept as comparable as possible, which means that for both routes the following applies:

- The route is circular;
- Start/end location is at the most Southern part of the route;
- A prominent landmark (church) is visible from start/end location;
- Mostly residential, some commercial and public buildings;
- The walking direction is clockwise;
- The length of the route is 1.6 kilometres;
- There are 10 corners and thus 10 'route segments';
- Most turns have a right angle;
- There are 3 left and 7 right hand turns.

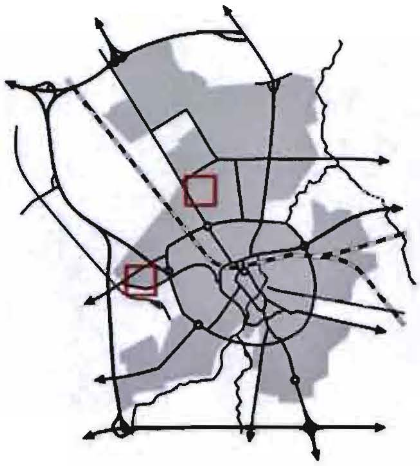


Figure 3.1 The two neighbourhoods located in Eindhoven (map from tue.nl).
Left: 'Het Ven', route A; Right: 'Barrier', route B (Gemeente Eindhoven, 2000).

Figure 3.2 Route A. Left: Areal view. Right: Street map with route (Both from www.maps.google.com).

Figure 3.3 Route B. Left: Areal view. Right: Street map with route (Both from www.maps.google.com).

More information and photographs of both routes can be found in appendix D: 'Study area'.

3.2 Experiment design

To answer the research question two experiment groups are created; one of them is navigating through the environment with use of an electronic navigation device and the other is doing so with a paper map. These groups are chosen because they represent the most used present day navigation aids, the device being the newcomer. Besides simple map display and turn by turn guidance it usually has a whole range of other functionalities. It is however important that the two experiment groups are as comparable as possible, apart of course from the aspects that are being tested. Therefore, a close look should be taken at the exact aids that are used in the experiment (as done in section 3.5).

For both groups it applies that the (identical) route the participants have to walk is shown. The amount visible at one time however differs per group due to characteristics of the used aids. The groups can be defined as follows (see also sections 2.5.1 and 2.5.2 for an explanation of characteristics):

1. *Paper map:*
   2D north-up map with route (all of the route and area is visible at one time)
2. *Electronic navigation device:*
   2D head-up map (only a small part of the route and area is visible at one time)

Note that half of the participants of each group will be assigned to each route (route A or route B).

Basically, this study has a 'between subjects design'. This means that each participant is assigned to one experiment group, and that he only experiences this one condition. Answers and reactions from participants in one group are compared to those in the other group. However, some parts of the study (the Santa Barbara Sense of Direction test and tasks in part III and IV of the experiment; see section 3.4) have a 'within subjects design'. Here, the same participant performs the same task a number of times, in order to measure differences over time.

3.3 Participants

Students following the second year course 'Urban Plans' (Stedenbouwkundige Plannen) at the University of Technology in Eindhoven (TU/e) have been approached and asked to participate in the study. In return they would receive 2 out of 10 points for the exam of the course. At the moment of approach, and also during the entire duration of the experiment, the students are told as little as possible about the subject and aim of the study in order to make sure that found results are not influenced by any foreknowledge.

The goal is to get 60 participants in total. This would mean that each group (per neighbourhood per experiment group) consists of 15 participants. That way the groups are large enough to perform data analysis, and still are of a manageable size for the experimenters.

The choice to use students as participants is partly made for practical reasons, since they are easily approachable and probably eager to participate because of the awarded course credit. Also, having only students as participants has many benefits, as they probably have some things in common such as age, 'spatial education' and interest for the built environment. Differences will exist in for example their cognitive spatial structures and their experience with and use of different types of navigation aids. Since the aim of the study is to investigate differences in spatial knowledge gaining between using a paper map and an electronic navigation device, and not necessarily to extrapolate findings to the general public, the use of only students as participants is not a disturbing fact.

Participants are allocated to one of the two experiment areas by initially looking at their current residential address and making sure that this is not close to their assigned area, in order to reduce the probability that they already know the area. Secondly the allocation is done randomly, taking into account only the ratio of males/females for each area. Allocation to the two experiment groups is done randomly as well, again only taking gender into account. The preferred allocation of participants is visualised in figure 3.4.

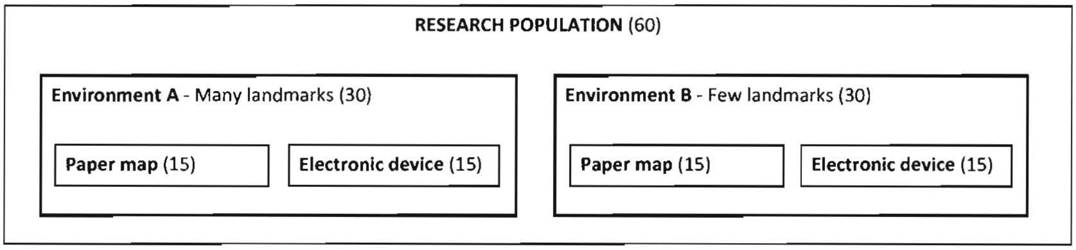


Figure 3.4 The total research population is initially divided over the two neighbourhoods and secondly over the two experiment conditions. Between brackets the amount of individuals wanted in each group.

The course 'Urban Plans' is in Dutch, so all students responding will be Dutch as well. To avoid them from holding back anything due to language barriers in their responses during the study, all communication with them and the tasks in the experiment are in Dutch.

3.4 Procedure

The experiment as conducted is divided in four parts; an internet questionnaire, the walking of the route, a questionnaire at the TU/e with several tasks and the same questionnaire one week later at the same location. In the following sections those four parts are explained.

3.4.1 I: Subscription & filling out an internet questionnaire

Upon subscription participants receive an e-mail with a link to an internet survey, including an availability check. After filling in the survey, participants receive an e-mail with information about times and locations where they are expected for their share of the field experiment.

In sections 3.6.1 and 3.6.2 this part of the experiment is explained more in detail. The sent e-mails and screenshots of the internet survey can be found in appendix A: 'Communication with participants' and appendix B: 'Internet survey'.

3.4.2 II: Walking the route

At the indicated time, the participant comes to the experiment location he is allocated to. All participants come individually, and are scheduled to arrive every 30 minutes.

Upon arrival the participant is welcomed by the experimenter and instructed about the different stages of the experiment, without giving away hints about the purpose of the study. After this, a question about familiarity with the area is asked. Then, the participant is given a GPS-tracker and –according to the condition he is assigned to– either a handheld navigation device or a printed map. To each participant the start direction of the route is indicated and he is told to just walk the route as indicated, and that further tasks will follow upon return. Furthermore he is told not to engage in any other activities such as eating, making a phone call or listening to music.

After the participant completes the route, and after handing back the GPS-tracker and the navigation aid, he is again asked the question about familiarity with the location. Subsequently the participant makes direction estimations on a circular pointing device to three locations he passed while walking.

Following the completion of this task the participant is told where to go for the next part of the experiment. This location is the Faculty of Architecture, Building and Planning at the TU/e campus, and when necessary route instructions are given on how to reach this location. The tasks and observations from this second part of the study are put out in sections 3.6.3 to 3.6.7.

3.4.3 *III: Tasks about the route*

At the TU/e the second experimenter is awaiting the participant. She hands over a package with a description of the tasks, several answer sheets, three envelopes with photographs and writing utensils.

During this part of the experiment the participant completes several tasks related to the route he just walked, such as drawing a sketch map, writing route directions and ordering photographs (see appendix E: 'Questionnaire and answer sheets' for the total questionnaire). Several times the participant has to hand in one answer sheet before getting the next one. This is necessary to ensure that some information stays unavailable until a later moment. The second experimenter coordinates this distribution, and she also makes sure that after completing a separate task the time of that moment is indicated which makes it possible to see how long a participant has been engaged in the different tasks. The final task includes a questionnaire about the use of navigation aids in general and some questions about the location of some main buildings in the city centre of Eindhoven. All tasks are described in detail in sections 3.6.8 to 3.6.15.

After handing everything back to the experimenter the participants' appointment for one week later is confirmed. Before being dismissed he is asked not to talk with anybody about the contents of the experiment, in order to make sure that other participants start the experiment without any foreknowledge.

3.4.4 *IV: Tasks about the route, administered one week later*

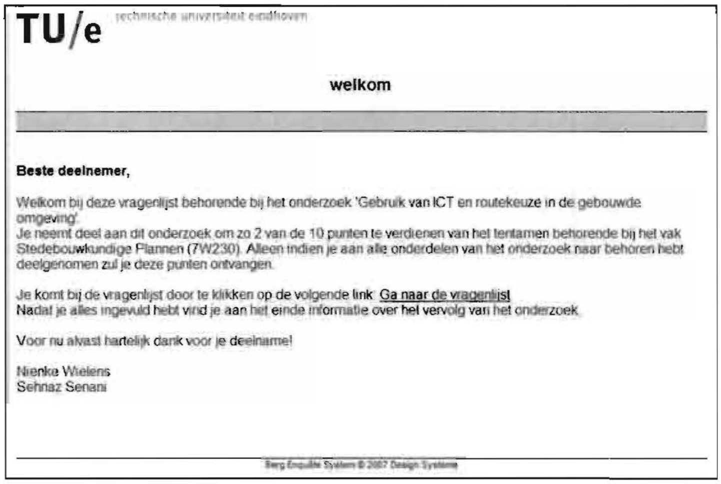
One week after walking the route and finishing the tasks at the university, the participant comes back to the TU/e to again complete a set of tasks. These tasks are identical to the ones in part III, only the final questionnaire about navigation aids is excluded. The procedure is the same as the week before.

This repetition of tasks at a later moment is done in order to see how spatial knowledge decays over time (see section 2.4.2 about the process of learning), and whether there is a difference in remembrance between map and device users.

3.5 Devices and programs

For gathering information and data, and later for evaluating those, several devices and programs are used. The most important ones –the Internet survey system, GPS-tracker, electronic navigation device and the paper map– are described below. For the data entry and analysis the programs Microsoft Excel and SPSS are used.

The first data of the study are gathered with an in-house developed Internet survey system. By means of this online program it is possible to set up a questionnaire. Both 'open' and 'closed' –such as multiple choice– questions can be asked. The system records the answers given, as well as the IP address of the computer and time of completion. These data can then be downloaded by the experimenter and opened in SPSS, so analysis will become possible. In figure 3.5 the first page of the questionnaire can be seen, in appendix B: 'Internet survey' the whole questionnaire can be found.



welkom

Beste deelnemer,

Welkom bij deze vragenlijst behorende bij het onderzoek 'Gebruik van ICT en routekeuze in de gebouwde omgeving'.
Je neemt deel aan dit onderzoek om zo 2 van de 10 punten te verdienen van het tentamen behorende bij het vak Stedebouwkundige Plannen (7W230). Alleen indien je aan alle onderdelen van het onderzoek naar behoren hebt deelgenomen zul je deze punten ontvangen.

Je komt bij de vragenlijst door te klikken op de volgende link: Ga naar de vragenlijst
Nadat je alles ingevuld hebt vind je aan het einde informatie over het vervolg van het onderzoek.

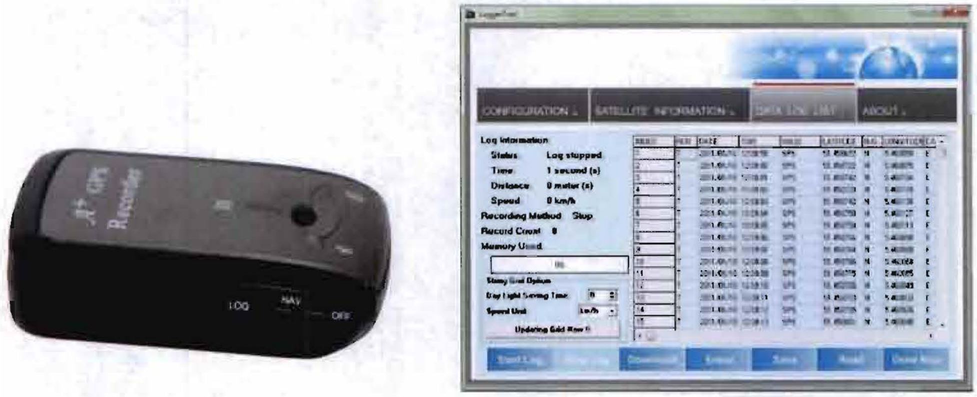
Voor nu alvast hartelijk dank voor je deelname!

Nienke Wielens
Sehnaz Senani

Berg Enquête System © 2007 Design Systems

Figure 3.5 Screenshot of the introduction page of the internet survey.

During their walk all participants carry a GPS-tracker in order to follow their movements. The used model is 747 A+, which is available for use at the Urban Planning Group of the Faculty of Architecture, Building and Planning at the TU/e. The tracker records GPS data at an interval that can be chosen; for this study the interval-time is 1 second. After the participant has walked the route, data from the tracker are downloaded to a computer by means of a special programme delivered with the device. After downloading the data are saved both as a Microsoft Excel-file and a KML-file, which can be viewed in Google Earth (User Manual 747A). The tracker and a screenshot of the accompanying programme can be seen in figure 3.6.



Log Information
Status Log stopped
Time 1 second (s)
Distance 0 meter (s)
Speed 0 km/h
Recording Method Stop
Record Count 0
Memory Used

Figure 3.6 The GPS-tracker participants carried with them during the experiment.
Left: GPS trip recorder, model 747 A+. Right: the interface on the PC for reading the data from the tracker.

The experiment group that is assigned to the electronic navigation device uses the Navigon 2510 Explorer with a 3,5-inch display (8,9 cm diagonal). This device is chosen because of its features. The first important aspect is that it has a special pedestrian mode which is needed for the experiment. Furthermore it is essential to be able to store a specific route in the device. This can easily be done, in such a way that for all participants the given information about the route is exactly the same. All features except for street names and a north-indication are turned off during the experiment. The only instructions for the participant are visual; an orange line indicating the route to be followed, an arrow at the current location and a green line where he has been. The device is set in such a way that the arrow is always in the middle of the screen, pointing up (making it a head-up map, see section 3.2) and that at every instant only a small part of the route is visible. The experimenter programmes the device prior to the walk, so the participant doesn't have to do anything with the device, except for following the route as indicated. The participant is not able to zoom in or out. During the experiment the device is covered in a clear skin for protection, as seen in figure 3.7.

The other experiment group uses a printed paper map, which can be seen in figure 3.8. The whole route is visible at all times, as well as a north-arrow and street names. The basis for the maps is copied from maps.google.com, which is done because this is a very well known and much used site by many people. This service can be used free of charge and it gives very accurate route information. It is important to choose a type of map that is quite well-known, in order to make the experiment more lifelike.

Figure 3.7 Navigon 2510 Explorer. Left: The device in its protective skin.
Right: The vertical walking modus as used in the experiment, with a part of the route visible.

The maps from the internet are edited in such a way that all information (such as land-use and shop names) except for the street names is deleted, in order to make the electronic and the paper map as comparable as possible regarding the visual information they give. All participants in the paper map condition receive a new, wrinkle free, colour copy on an A4 sheet of paper.

Figure 3.8 The paper map, printed in colour on an A4 sheet of paper. Left: route A. Right: route B.

3.6 The experiment in detail: the tasks used in this study

In the following sections all the conducted tasks and gathered data are described. In table 3.1 all of these are summed up in chronological order of when the data are gathered. In the first column the type of information wanted is described, in the second the measurement method and in the last column a number referring to the corresponding section below, and a letter referring to that part of the questionnaire as used in part III and IV of the study (for the total questionnaire as conducted, have a look at appendix E: 'Questionnaire and answer sheets').

As can be seen in table 3.1, a distinction is made between two types of tasks for part III and IV of the experiment. The first four are about *recollection*, which means how much the participant can recall from his own memory and his formed cognitive map, without the presence of any items that might help him remember. The next three tasks can be classified as *recognition* tasks. For these tasks it wasn't necessary to recall information, but only to recognise, or in other words to remember the item in presence of the item (Arthur & Passini, 1992; Bell, 2001). For all three recognition tasks photographs of the environment are used, and the participant has to indicate whether he has seen the locations on the photographs before, place them in the right order, and locate them on a map. The recollection tasks are placed before the recognition tasks in order to let the participant think for himself, before providing him with material that could help him with that. Within each type of task the different parts are ordered in such a way as well, to keep information from the participant as long as possible. Something to be kept in mind however is that even though the participant does not know the content of part IV before making it, he has performed all tasks before in part III. Therefore it is possible that he remembers certain aspects not from walking the route, but from writing it down in part III.

3.6.1 Questionnaire with general questions and availability-check

Before taking part in the actual experiment, some information is needed from the participants. The conducted internet survey includes questions about age and study, but also the current residential address and former addresses in Eindhoven. The latter is done because in that way it is possible to allocate the participant to an experiment area he is probably not very familiar with. Furthermore, questions about availability are asked, in order to be able to schedule the participant at a convenient moment. In appendix B: 'Internet survey' the total internet survey can be found.

Table 3.1 All tasks and data gathering moments of the study.

Information wanted	Measurement method			
I - Subscription & filling out an internet questionnaire				
Basic information such as demographics, bike ownership, familiarity with Eindhoven, moments of availability etc.	Questionnaire with general questions and availability-check		1	
Self-perceived sense of direction	SBSoD self scale test (1/3)		2	
II - Walking the route				
Familiarity with location	Question about familiarity		3	
Orientation and survey knowledge	Direction estimation with circular pointing device		4	
Duration of the trip	GPS-tracker		5	
Number of stops en-route	GPS-tracker		6	
Correctness of walked route	GPS-tracker		7	
III - Tasks about the route				
Landmark, route, and survey knowledge	Sketch map drawing – draw the route and striking features on an empty background	Recollection	8	A
Landmark and route knowledge	Giving navigation directions		9	B
Route knowledge	Drawing the walked route on a map of the environment		10	C
Landmark and survey knowledge	Marking striking features on the map on which the correct route has been indicated		11	D
Landmark knowledge	Landmark and intersection recognition from photographs	Recognition	12	E
Route knowledge	Ordering photographs of intersections in the right sequence		13	F
Route and survey knowledge	Placing photographs of intersections at the correct location on the map		14	G
Self-perceived sense of direction	SBSoD self scale test (2/3)		2	H
Background information of the participant	Questionnaire about the experiment, general questions about use of navigation devices and about spatial knowledge of Eindhoven		15	H
IV - Tasks about the route, administered one week later				
The tasks from part III are performed again, with exception of only the final questionnaire.				

3.6.2 *Santa Barbara Sense of Direction self scale test (SBSoD)*

As already described in section 2.6.4, Hegarty and colleagues (2002) have developed a self report scale which indicates the amount of *sense of direction* a person perceives to have. They have proven it to be a useful instrument for predicting environmental spatial abilities.

During the present study, the Santa Barbara Sense of Direction test is filled out three times by each participant. The first time before the experiment (during the internet survey), the second time after the participant has walked the route and completed tasks about it, and the third time after completing the tasks again one week later. The reason why participants fill out the test three times, is to be able to see whether there are any differences in their self perceived sense of direction, depending on what stage of the experiment they are in. It is imaginable that just after completing the tasks one might think their sense of direction is better or worse than at the moment when they have not yet been engaged in spatial tasks. Furthermore can outcomes of the test be compared to performance on the other tasks, to see whether there is a relation between the two.

3.6.3 *Question about familiarity*

In order to interpret the gathered data correctly, it is important to know whether a participant has been at the experiment location before. Therefore a question is asked before and after walking the route. The question is as simple as 'have you been at this location before?' and if the answer is yes: when, how often and for what occasion. The same question is asked again after finishing the walk, since the participant might have recognised another part of the route.

3.6.4 *Direction estimation with circular pointing device*

Directly after the participant walks the route, he performs a task indicating directions to locations he has just seen while walking the route, to measure orientation and route knowledge. He does this on a circular pointing device, which can be seen in figure 3.9. A similar device is used among others by Willis et al. (2009), Ishikawa et al. (2008) and Hegarty et al. (2002), as described in section 2.6.2.

The procedure of this task is that firstly the experimenter indicates where exactly the participant has to be standing and which way he should be facing. Then, a photograph of a certain junction or landmark is shown, and the participant has to indicate on the device in which direction that location is, by placing a mark and the accompanying number, as were it a compass. Three different photographs are shown to the participant; the church (visible from the place he is standing for both environments), a street junction where he made a turn, and a playground for children which he passed while walking. In appendix F: 'Photographs for orientation and recognition tasks' the used photographs as well as the locations of them on the map can be found.

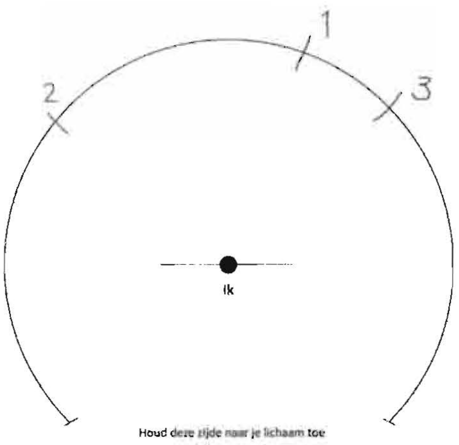


Figure 3.9 The circular pointing device. In real life the device is approximately the size of an A5, printed on an A4 sheet of paper.

3.6.5 GPS-tracker – Duration of the trip

In order to compare the amount of time participants take to finish their walk, the duration of their walk is recorded. The GPS-tracker the participant carries with him during the walk records the time and location every second. This means that both location and time are very accurately measured, enabling to calculate how much time is needed to complete the route. As a backup, the experimenter records the time of start and arrival as well.

3.6.6 GPS-tracker – Number of stops en-route

It is believed that when a participant stops while walking the route, this is done to reorient himself or to take a look at the map, since they are told not to engage in any other activity during the walk. The participant is carrying the GPS-tracker, which makes it is possible to see where he has made a (brief) stop.

3.6.7 GPS-tracker – Correctness of walked route

The GPS-tracker records the route, so it is possible to see whether the participant has walked the route correctly and has not made any wrong turns or shortcuts. This observation is therefore purely a check-up to see whether the participant does what he is supposed to be doing.

3.6.8 *Sketch map drawing*

The first task from the booklet the participant is handed at the TU/e is the first of four recollection tasks. The participant is asked to draw a sketch map of the route he just walked, including its surroundings. On the A4 answer sheet a few elements were already indicated in order to make the drawings better comparable for analyses; a north arrow (with the north pointing up), the origin of the route (start and end point), the location of the church and a scale bar were drawn; see figure 3.10.

Furthermore, some hints are give about possible items to draw or indicate on the map, such as street names, parks or green areas, street profiles, shops, schools and parking places. It is believed that a sketch map a person draws tells about the amount and type of spatial knowledge a person has at a certain moment (see section 2.6.1). In this study this means it shows the gathered amount of spatial knowledge, since the environment was new for all participants.

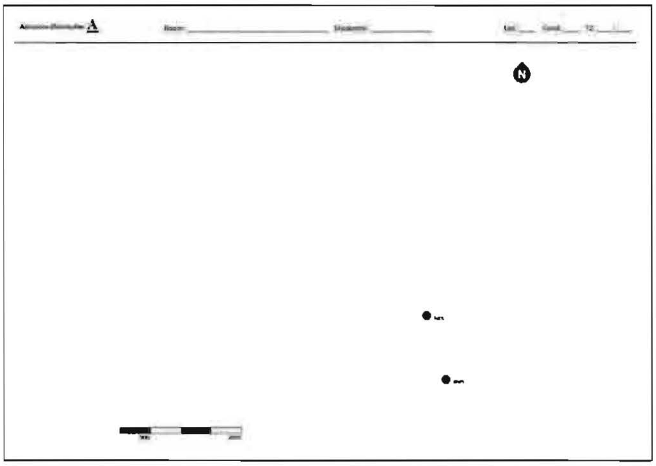


Figure 3.10 Answer sheet (A4) for drawing the sketch map. North arrow, origin, church and scale bar are indicated.

All three types of spatial knowledge; landmark, route and survey knowledge are tested with this task. The elaboration and correctness of the drawn landmarks, walked route and surroundings, and the type of map (route or survey, see section 2.6.1) give an indication of how much spatial knowledge is acquired.

3.6.9 *Giving navigation directions*

In this task, the participant is asked to give navigation directions, just like he is giving them to somebody who wants to know how to complete the route but is unfamiliar with the environment.

The given directions have to be written down. No hints are given as far as the format the text should be in. This is done in order to let the participant choose his own 'style' of giving directions, which means it is be possible to see whether the participant is more landmark oriented, or direction (route) oriented.

3.6.10 *Drawing the walked route on a map*

After writing down the navigation directions, the participant has to draw the route as walked on an answer sheet with a map of the environment. The map used for this and following answer sheets is deliberately different from both the map shown on the electronic device and the paper map, so that this specific representation of the environment is new for both experimental groups. The answer sheet is only given to the participant after he finishes the previous task, so he would not be tempted to take a peek. The participant is asked to indicate his walked route, including the direction he was going. In this task, mainly route knowledge is tested, but in order to draw the route at the correct location some survey knowledge is needed as well. The answer sheet used for this task can be seen in figure 3.11.

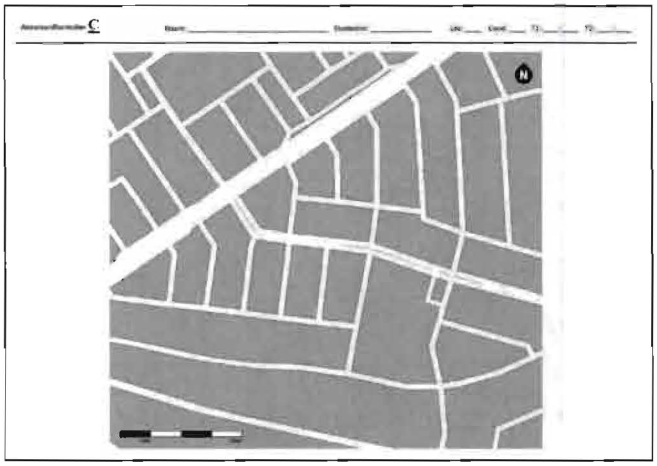


Figure 3.11 Answer sheet (A4) with the street pattern, north arrow and scale bar.

3.6.11 *Marking striking features on a map*

This final recollection task is in its essence the same as the sketch map task as described in 3.6.8. The big difference however is that this time the basic map and the correct route are already indicated on the answer sheet, as shown in figure 3.12. This means the participant has a guide for placing landmarks and other features at the correct location on the answer sheet; this might result in a different placement of items than in the initial sketch map task.

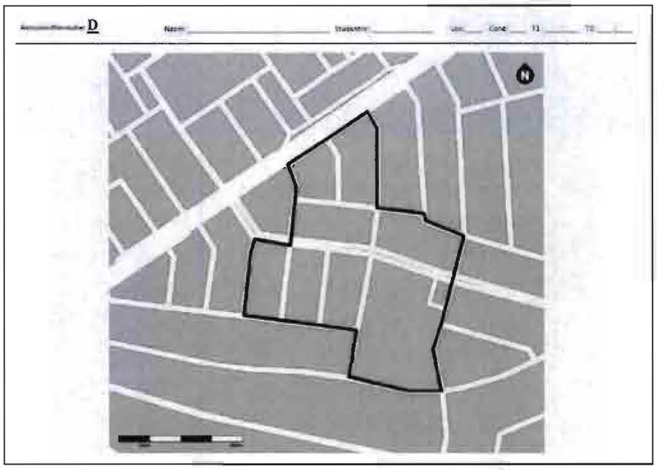


Figure 3.12 Answer sheet (A4) with basic map and route.

3.6.12 *Landmark and intersection recognition from photographs*

This is the first of three recognition tasks. In the first of the three envelopes the participant receives with the questionnaire are 24 photographs. All photographs are numbered from 1 to 24, and are randomly stacked; which is done by the experimenter before each participant. This is done to make sure that the order of seeing the photographs has no influence on the participant's answers. On the photographs are locations the participant could have seen while walking the route (and two 'fake' photographs of locations in the other experimental area).

The photographs are printed on A4 sheets of thick paper, which are cut in half lengthwise. In figure 3.13 two examples are given and all used photographs and their location on the map can be found in appendix F: 'Photographs for orientation and recognition tasks'. For both the experimental locations the following types of photographs are included:

- 10 landmarks (stores, buildings, playground etc.)
- 5 street views (180° view straight ahead)
- 4 corners (270° view at a street corner where a turn was made during the walk)
- 3 details from houses (fence, coloured front door, remarkable pathway, garden gnomes, etc.)
- 2 'fake' photographs (one street view and one detail from a house taken from the other experiment area)

Figure 3.13 Example of photographs of locations the participant could have seen during his walk. Top: 'street view'. Bottom: 'detail from house'.

Besides indicating whether to have seen the location on the photograph before, the participant also has to indicate his certainty about these choices (see Figure 3.14).

1. Ik herken deze locatie ☐ wel ☐ niet
erg onzeker 1 2 3 4 5 erg zeker

Figure 3.14 For each photograph the participant indicates whether he recognises the location, as well as his certainty about this.

With this recognition task landmark knowledge is measured. The participant only has to indicate whether he recognises the photographs; there is no need to relate them to each other or to place them at a specific location.

3.6.13 Ordering photographs of intersections

To test the route knowledge a participant has acquired, he performs a second recognition task. In this task, he is required to place photographs of corners and street views in the correct order as how he has seen them while walking the route (see for the used photographs appendix F: 'Photographs for orientation and recognition tasks').

In the second envelope the participant has received at the start of the questionnaire, there are nine photographs. They are printed in the same fashion as done for the landmark recognition task, and numbered from *I* to *IX*. This is also the initial order all photographs are placed in -done so by the experimenter before using them again- and the participant places the photographs in the order he thinks is correct, and marks this order on the answer sheet (see figure 3.15).

Volgorde:

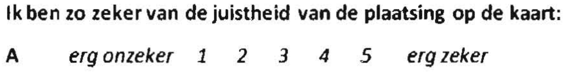
1.	2.	3.	4.	5.	6.	7.	8.	9.
IV	___	___	___	___	___	___	___	___

Figure 3.15 The participant indicates the order he thinks the photographs should be in.

For the actual ordering the participant may choose to hold all photographs in his hand, or to organise them on the table in front of him. The first correct placement is already given (number IV, see above), this is the start location of the route.

3.6.14 Placing photographs of intersections at the correct location on a map

The same photographs from the ordering task are used again in this task which measures both route and survey knowledge. However, this time they are labelled with the letters A to K, placed in envelope 3, and a photograph of the church is added. Again, the experimenter makes sure that the initial order is from A to K, to make sure all participants receive the same package. The participant is required to indicate the correct location of the photograph on a map with the route drawn in (the same as used for the task described in 3.6.11, see figure 3.12). After doing this he also indicates how sure he is about this placement on the map (see figure 3.16).



Ik ben zo zeker van de juistheid van de plaatsing op de kaart:

A *erg onzeker 1 2 3 4 5 erg zeker*

Figure 3.16 After marking the location of the photograph on the map, the certainty of this placement is circled.

3.6.15 Questionnaire

This final questionnaire consists of several types of questions, and is only conducted in part three of the study since it does not measure spatial knowledge and therefore does not need repetition. After finishing the SBSoD self scale test, the participant answers questions about his use of different navigation aids in several situations. These are followed by questions about handiness, satisfaction, benefits and disadvantages of using an electronic navigation device in general. The participant is also asked to indicate for what purpose he usually uses an electronic navigation device, and what type of aid he would use if he had the choice.

The two final questions are not part of the current study, but have a great deal to do with the subject area and are therefore included. In the first one the participant marks 15 types of landmarks on a map which contains the city centre of Eindhoven (see figure 3.17). The categories -e.g. supermarket, church, hotel, and stadium- are given and numbered, and the participant has to indicate one instant of each category on the map, accompanied by the corresponding number. Finally, the participant (when living in Eindhoven) gives written route descriptions from his house to the university. This is quite similar to the task in section 3.6.9 and can be analysed the same way.

In section H of appendix X: 'Questionnaire and answer sheets' all questions can be found.

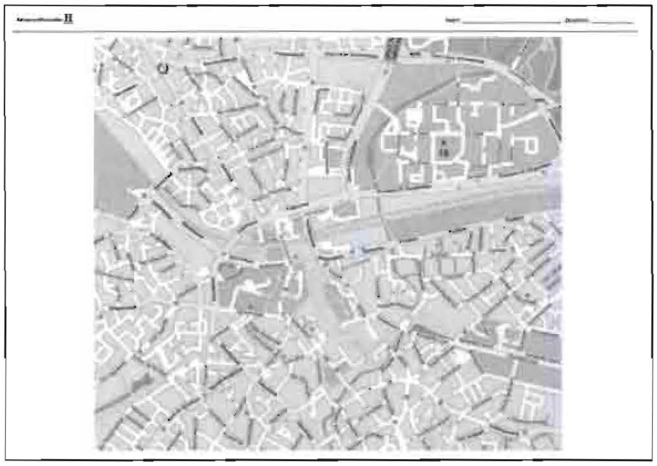


Figure 3.17 The answer sheet, printed on an A3 sheet, contains a map of the city centre of Eindhoven on which the participant indicates several landmarks.

3.7 Summary

To be able to answer the research question an experiment is performed. Two neighbourhoods in the city of Eindhoven are used for the data collection. These locations are chosen because of their similar characteristics, with as only difference the amount of landmarks that is present.

Participants of the study will be divided over two experiment groups, the first one using an electronic navigation device and the second a paper map. This means there will be two groups navigating through environment A, and two groups through environment B. Students from the course 'Urban Plans" are approached to participate in return for partial course credit.

The experiment is divided into four parts, the first part being an internet questionnaire with general questions, an availability check and the first administration of the Santa Barbara Sense of Direction self scale test. The second part of the experiment is the actual walking of the route and directly afterwards a direction pointing task where the participant indicated directions towards three locations seen en route.

The third and fourth parts are identical questionnaires which contain several tasks measuring spatial knowledge. The difference between the two is that the third part takes place immediately after walking the route, and that the fourth part is administered one week later, done so to measure possible decay of spatial knowledge. Furthermore, part three contains some extra questions about the use of different navigation aids and a task concerning knowledge about Eindhoven. Both questionnaires are conducted at the university. The entire questionnaire consists of seven tasks, the first four being recollection and the last three being recognition tasks, followed by the completion of the SBSoD self scale test;

- Sketch map drawing;
- Giving navigation directions;
- Drawing the walked route on a map;
- Marking striking features on a map containing the correct route;
- Landmark and intersection recognition from photographs;
- Ordering photographs of intersections in the right sequence;
- Placing photographs of intersections at the correct location on a map;
- Filling in the SBSoD self scale test.

4

RESULTS

4 RESULTS

In this chapter results of the conducted analyses are reported. Since the amount of collected data is so large, a selection of it is analysed based on the framework and research questions asked in this thesis. There is chosen to analyse the first, second and third part of the study. The fourth part -the questionnaire the participants answered one week after their walk- is thus excluded. Therefore, at this moment no answers can be given to questions concerning the decay of spatial knowledge over time.

Secondly, a further selection is made with the choice to omit some tasks from analysis. The data that are analysed include the two administrations of the SBSoD self scale test (the first during the internet survey and the second in part III of the experiment), the direction estimation task in the field, the route drawing task, and all recognition tasks; landmark recognition, the ordering of intersections, and the placing of intersections on the map. The collected data are gathered in a SPSS file. A codebook with all variables can be found in appendix H: 'Codebook'.

In section 4.1, general characteristics of the participants as well as conditions during the data collection are described. After that, results are given per task or data collection moment, divided over sections in the same fashion as done in chapter 3. In section 4.3 relations between the different analysed tasks and the SBSoD self scale test are explored, followed by a conclusion.

4.1 Participants

All data collection took place between November 2010 and January 2011. During this period the weather conditions were rather constant, but given the time of year temperatures were quite low; around or just above freezing. Participants that were initially scheduled for days with rain or snowfall have been rescheduled to other days. This did mean though that for some participants (six in total) there was some snow lying on the ground from snowfall the days before. The sidewalks where had to be walked on however were free of snow, so no dangerous situations have emerged. During the walk of one participant there was a little drizzle.

The desired number of participants, sixty, has been met. The approached students were in fact very eager to participate and reacted immediately on the invitation to do so. All of the participants have completed all parts of the study. Coincidentally there reacted exactly 20 female students, so the diagram from figure 3.4 now can be updated to figure 4.1. As said before, the participants are divided over the experiment groups randomly, only taking into consideration possible familiarity with the environment (based on home address) and gender.

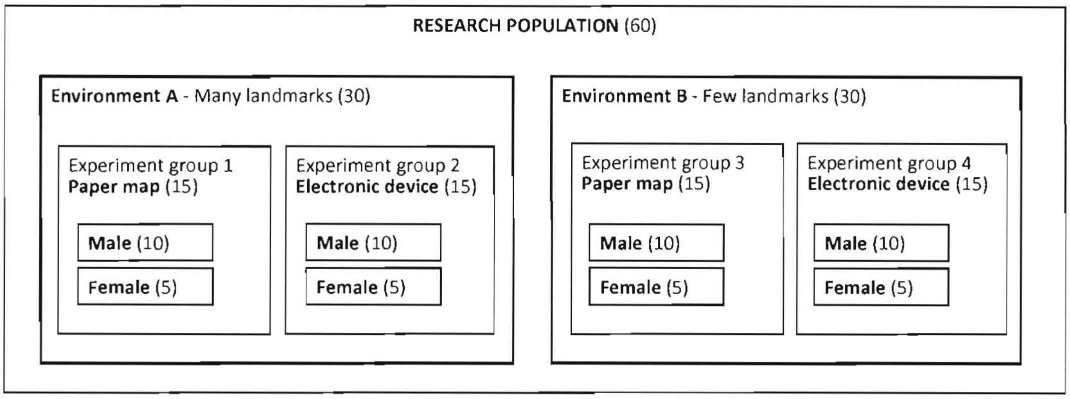


Figure 4.1 The total research population is initially divided over the two neighbourhoods and secondly over the two experiment conditions. Between brackets the amount of individuals in each group.

The mean age of participants is 21.1 years (SD = 4.0); this distribution of age is shown in figure 4.2. For the separate experiment groups this mean is comparable. A table with this information can be found in appendix I: 'Analysis' (table 1). Given the small scatter of age, it will not be interesting to investigate differences in answers regarding age.

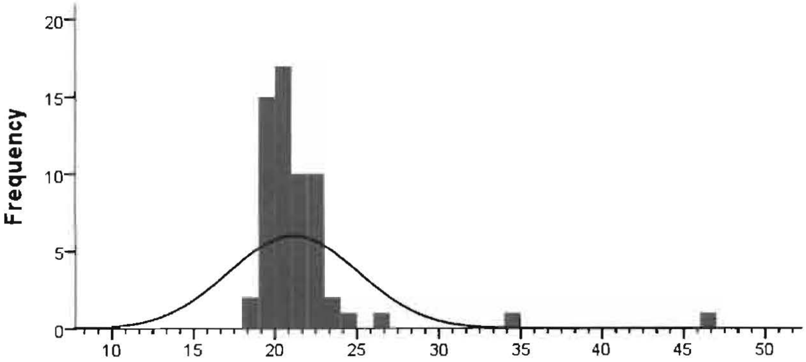


Figure 4.2 Distribution of age of the total group of participants.

All participants study Architecture, Building and Planning, except for one; this participant studies Innovation Sciences (also at the TU/e). Over 50 percent of participants started their study in 2009, almost 40 percent started in 2007 or 2008, and the other 10 percent started in 2004 or 2005.

Three quarters of the participants lived in Eindhoven at the moment of data collection, and this distribution is about the same per experiment group (see appendix I, table 2). About one quarter of participants lived at another address in Eindhoven before their current address.

4.2 Results per observation-moment

In the following sections results of the conducted analyses can be found, ordered per task or data collection moment. In each section some explanation is given considering the methods of analysis, and after that the results of different tests are described.

For most tasks, the used tests are Paired or Independent Samples t-tests (for testing the equality of means of groups), and correlation analysis. Even though the two experiment locations are kept as comparable as possible, differences do exists in for example the exact shape of the route and the used photographs for recognition tasks. Therefore, most relevant is to compare the paper map and electronic device groups per location instead of the total groups for both locations combined.

In general, it is expected that participants using the electronic device perform worse on all tasks than the paper map users. This hypothesis is based on the findings of Parush et al. (2007) and Burnett and Lee (2005) as explained in section 2.5.3.

4.2.1 Questionnaire with general questions and availability-check

The information gathered with the internet survey is mostly described in section 4.1. The results of the first administration of the SBSoD self scale test can be found in section 4.2.2.

Most participants were quite flexible regarding their availability and indicated many moments they were available; the puzzle of making a schedule was therefore not too difficult.

4.2.2 Santa Barbara Sense of Direction self scale test (SBSoD)

The results from the first and second administration of the Santa Barbara Sense of Direction self scale test are included here. The internal reliability (Cronbach's α) of the test and differences between administering moments are analysed.

Some of the questions of the scale are stated positively (1, 3, 4, 5, 7, 9, and 14), the others negatively (see appendix C: 'SBSoD'). Therefore, before performing any tests, the answers of positively stated questions are reversed so that a higher score indicates a better sense of direction, ranging from 1 to 7. The mean score per participant over the 15 items is used for the analyses.

Hegarty et al. (2002) found an internal reliability of $\alpha = .88$ for the test. This is a good score, indicating that all items of the test measure 'the same thing'. In the present study, internal reliability of the test is calculated as well. The Cronbach's α and mean scores on the test can be found in table 4.1. The full Item-Total statistics can be found in appendix I (table 3 and 4).

Table 4.1 Cronbach's α and mean scores of the SBSoD self scale test

SBSoD 1		SBSoD 2	
Cronbach's α	.865	Cronbach's α	.831
Mean	4.783	Mean	4.769
SD	.9174	SD	.8518

The found internal reliability for both SBSoD tests in the present study is good, and almost the same as the score found by Hegarty et al. (2002). Paired Samples t-tests are performed to see whether the mean scores of the SBSoD tests differ significantly between the two administering moments. This has been done for the total group of participants, as well as for the four different experiment groups. For none of these a significant result could be found (see appendix I, table 5), which indicates that participants did not fill in the test differently during the internet survey or directly after completing the spatial tasks. Again, these results are in line with those of Hegarty et al. (2002), who could not find a significant difference between two moments of administration with spatial tasks in between.

Furthermore, Independent Samples t-tests are performed to check for differences in means between the paper map and electronic device groups in total, as well as divided per environment. None of these tests are significant, indicating that there are no differences between groups.

4.2.3 *Question about familiarity*

Participants are assigned to an experiment location, taking into account their current and previous residential addresses. Despite this precaution, some participants reported to be more or less familiar with the location they were allocated to, see table 4.2.

One participant (route B, device) knew the location because his parents live close by; the other five only recognised the location from riding past or through it on an incidental basis. Since the number of participants recognising the location is so low, this aspect is not included in further analysis.

Table 4.2 Familiarity with the location

	Familiar with the location?		Total
	no	yes	
Route A, map	14	1	15
Route A, device	15	0	15
Route B, map	13	2	15
Route B, device	12	3	15
Total	54	6	60

4.2.4 *Direction estimation with circular pointing device*

In their experiments, Hegarty et al. (2002), Ishikawa et al. (2008) and Willis et al. (2009) all calculated the absolute error of direction estimation. They used the mean absolute angular error in their analyses. The same has been done in the present study. The absolute error of direction estimation is measured by subtracting the actual angle from the estimated angle, and making this result absolute. The correct answers of this task -with indications on the map- can be found in appendix G: 'Correct solutions to tasks'.

For all three orientation tasks -pointing at the church, the playground, and a corner- a mean absolute error has been calculated per experiment group and per route. Furthermore, a mean of these mean errors is calculated, which can be considered a total score for this task. The results can be seen in table 4.3. Note that a higher score means a worse orientation, since error scores are used.

Table 4.3 Mean absolute angular error of direction estimation

	Route A, map (n=15)		Route A, device (n=15)		Route B, map (n=15)		Route B, device (n=15)		All participants (n=60)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Church	2.33	1.543	4.60	5.011	14.27	13.926	13.60	14.803	8.70	11.537
Playground	30.80	24.116	24.80	17.247	14.20	7.350	16.93	10.990	21.68	17.136
Corner	17.20	21.281	16.13	14.162	25.60	18.508	21.00	20.139	19.98	18.617
Total mean	16.78	14.344	15.18	9.030	18.02	9.993	17.18	7.973	16.79	10.394
	Paper map (n=30)		Electronic device (n=30)		Route A (n=30)		Route B (n=30)			
	Mean	SD	Mean	SD	Mean	SD	Mean	SD		
Church	8.30	11.472	9.10	11.784	3.47	3.821	13.93	14.125		
Playground	22.50	19.445	20.87	14.762	27.80	20.825	15.57	9.291		
Corner	21.40	20.056	18.57	17.284	16.67	17.769	23.30	19.148		
Total mean	17.40	12.163	16.18	8.431	15.98	11.805	17.60	8.893		

What can be seen is that the angular errors differ quite a lot per pointing location and also per environment; this is probably due to de differences in difficulty. For example, the church was visible from the location of standing for both groups and as a result the error is smaller for this pointing location than for the direction estimation towards playground and corner.

Route B participants however did perform significantly worse than route A participants on pointing towards the church ($p < .01$), which might be due to the fact that the church in environment A was straight ahead of the participant and not so in environment B. The difference in mean between route A and route B on pointing towards the playground is also significantly different ($p < .05$). However, as said before, differences between routes are most likely to be due to the chosen locations used for the task.

Of more interest is therefore the comparison of means of paper map and electronic device users per environment. It is noticeable that the total mean scores of map users are higher (worse) than the scores of the device users for both the environments, where would be expected that the map users perform better. These differences however do not come close to significance; neither do any other comparisons between groups. Only the comparison between map and device users from route A for direction estimation towards the church comes close to significance with a level of $p = .105$ (see appendix I, table 6 for results).

In conclusion, it can be said that the only differences in mean that exist can be explained by characteristics of the environments. This might be due to actual differences in appearance or amount of landmarks, but it can also be due to choice of pointing locations which are not equally difficult for routes A and B.

4.2.5 GPS-tracker – Duration of the trip

There are three different types of information that are gathered with the GPS-tracker which participants carried with them during their walk in the field; information about the duration of the trip, the number of stops en-route, and the correctness of the walked route. All participants carried the tracker, but unfortunately the device first of all did not register all data, and secondly recorded quite some 'impossible' data. For example, according to the tracker data, walks of some participants went right through houses or stopped and started somewhere halfway. A possible explanation of this failure is that the trip was too short or too slow (walking instead of cycling or driving) to make accurate measurements; every device which uses GPS signals needs to 'see' the open sky for some time to locate itself, and maybe this time was too short. Furthermore it could be the case that the set time interval of 1 second was too accurate and that an interval of for example 5 seconds would have been better. Why the tracker did not collect all data -not even the wrong information- from some participants is however not clear.

The time participants needed to complete the route is measured by the experimenter as well. However, this time is rounded to minutes meaning that the recording of time is not very accurate. The mean duration of the walk for all participants is 16 minutes. The mean time for the separate experiment groups is 16 minutes as well; except for the electronic device users in environment A, they walked 17 minutes. The duration of the walk is visualised in figure 4.3.

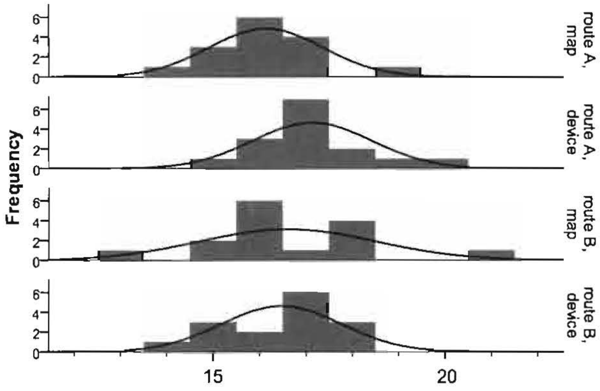


Figure 4.3 The distribution of duration of the trip in minutes.

Independent Samples t-tests have been performed to check for difference in mean between groups. Comparison of the total paper map and electronic device groups and the two groups in environment B did not lead to any significant results. The difference between groups for route A is significant ($p < .05$), which indicates that the device users indeed walked slower.

4.2.6 *GPS-tracker - Number of stops en-route*

As explained above, it is unfortunately not possible to count the number of stops participants made because of missing and incorrect data.

4.2.7 *GPS-tracker - Correctness of walked route*

In figure 4.4 two examples are given of the visualised tracker data in Google Earth. For some of the participants the data are complete, for others large parts are missing. These missing or incorrect data make it impossible to perform analysis. From conversations with participants however, there are no indications that anybody got lost or went a wrong direction during their walk.

Figure 4.4 Examples of the visualisation of tracker data in Google Earth. Left: the route is complete but the data sometimes show the participant walking through houses. Right: messy and incomplete data.

4.2.8 *Sketch map drawing*

In the context of this thesis, no sketch map analysis will be performed regarding this task (task A) and the sketch map task with a map background (task D). However, when analysis would occur, attention should be paid to for example (see also section 2.6.1):

- Route (sequential elements) or survey (spatial elements) type of map;
- Number of path segments from the walked route;
- Number of landmarks that are drawn/indicated on the map;
- The correctness of placement of landmarks; either in relation to other landmarks or to a path segment.

In figure 4.5 two illustrating examples are given of sketch maps drawn by participants who walked through environment A while using an electronic device; the difference between the sketch maps can immediately be seen.

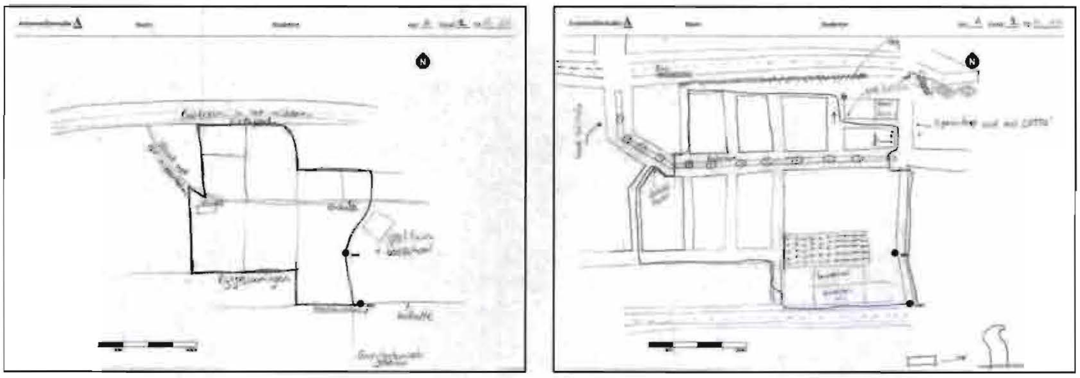


Figure 4.5 Two examples of sketch maps participants drew of environment A.

4.2.9 Giving navigation directions

In the context of this thesis, no analysis is performed on the given navigation directions.

4.2.10 Drawing the walked route on a map

Before analysis can be performed on this task, the drawn routes are graded so that each participant gets a score indicating how well he performed. For both routes the exact amounts of segments are indicated (path segments between possible decision moments); which can be found in appendix G: 'Correct solutions to tasks'. Per participant the amount of missed segments is indicated, and this amount is subtracted from a maximum score of 20. Furthermore, an extra point is subtracted when the direction indication is reversed for some part of the route. In figure 4.6 an example can be found of a participant who is rewarded with a score of 18 (20-2) points, since he missed two segments. The scoring of this task has been done by both the experimenters, to avoid subjective counts.

It should be noted –as can be seen in appendix G– that the total amount of segments to be drawn for a correct route is 18 for route A and 16 for route B. When deciding on the environments and the routes in it while designing the experiment, the amount of segments was calculated as being a connection between two turning points (corners). In this view both routes have 10 segments. When however segments are defined as connections between two *possible* turning points, the amounts are different between the two routes. It would mean that if participants in environment B outperform those in environment A, an explanation could be the difference in number of segments. In the analysis, this fact of different amounts of segments is however not taken into account.

Over all participants, the mean for route drawing is 18.57 (SD = 2.746). This indicates that overall the participants have drawn routes with on average 1.5 segments missing. The mean of scores per experiment group and per environment can be found in table 4.4.

Table 4.4 Mean scores for route drawing (maximum score is 20)

Route A, map (n=15)		Route A, device (n=15)		Route B, map (n=15)		Route B, device (n=15)		All participants (n=60)	
Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
19.20	1.521	17.20	3.342	19.60	1.549	18.27	3.494	18.57	2.746
Paper map (n=30)		Electronic device (n=30)		Route A (n=30)		Route B (n=30)			
Mean	SD	Mean	SD	Mean	SD	Mean	SD		
19.40	1.522	17.73	3.403	18.20	2.747	18.93	2.741		

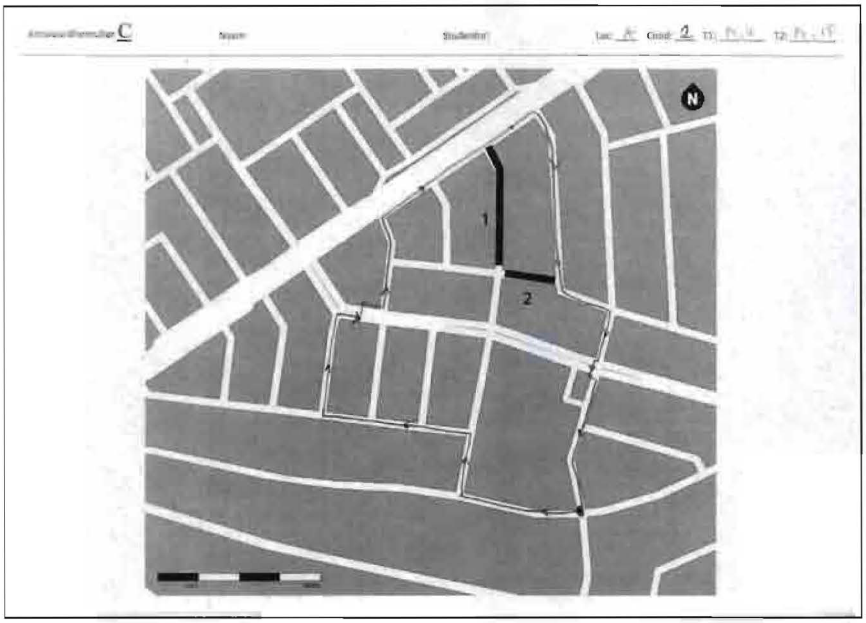


Figure 4.6 This participant receives a score of 18 (20-2) for this task.

Independent Samples t-tests are performed to test for the equality of means between groups. Results of these tests can be found in appendix I (table 7). When comparing the total groups of paper map and electronic device users, a significant difference ($p < .05$) between means is found, as well as for comparison of those groups for route A ($p < .05$) indicating that paper map users perform significantly better with a difference in means of 2 segments. No significant results are found for comparing route A and B, or within environment B. This indicates that the found difference in means for the total groups of map and device users can be explained solely from the strong differences found in environment A.

4.2.11 Marking striking features on a map

Like the other sketch maps task (task A), this task (task D) is not analysed within the context of this thesis. For analysis, the points of attention described under section 4.2.8 apply here as well.

4.2.12 Landmark and intersection recognition from photographs

Participants indicated for 24 photographs whether they recognised the location on it, and how sure they felt about this choice on a Likert scale ranging from 1 (very unsure) to 5 (very sure). Within the set of photographs, there are 2 which are taken from the other experiment location (photograph 11 and 23) and for which the answer therefore should be that they do not recognise the location. For all other photographs the answer is 'yes' since the participant could have seen the location during his walk. In appendix I frequency graphs of answers per landmark are shown, divided per experiment group. The mean certainty participants have indicated is shown as well.

In order to perform analysis, mean scores per landmark and mean scores per participant over all landmarks are calculated for both recognition and certainty. Before doing so, the answers to question 11 and 23 for recognition are reversed, so that a participant scores a '1' to a question when the correct answer is given, and a '0' when the answer is incorrect. Mean scores will therefore lie between 0 and 1, and a score closer to 1 indicates more correct answers. The mean scores of the certainty of placement will lie between 0 and 5, with a higher score meaning a higher certainty.

Landmark recognition

Independent Samples t-tests are performed to check for the equality of means for recognition per landmark. This is done between the paper map and electronic device groups divided by environment. These tests showed only a marginal difference: for route A number 6 (distant landmark) showed a significant difference in mean ($p < .05$), for route B no significant differences could be found. When comparing the mean scores per participant over all landmarks by Independent Samples t-tests, again no significant differences in mean are found (see table 4.5 and table 8 in appendix I). It thus can be said that participants in the map and device groups did not remember landmarks differently. No tests are performed comparing route A and B or the total map and device groups, since the use of different locations and different photographs makes the two locations incomparable.

Table 4.5 Mean scores for landmark recognition (maximum score is 1)

Route A, map (n=15)		Route A, device (n=15)		Route A (n=30)	
Mean	SD	Mean	SD	Mean	SD
0.60	0.089	0.58	0.076	0.59	0.082
Route B, map (n=15)		Route B, device (n=15)		Route B (n=30)	
Mean	SD	Mean	SD	Mean	SD
0.63	0.120	0.64	0.113	0.64	0.115

Certainty of landmark recognition

Next, the same tests are performed, but now for the certainty of choice. When comparing per landmark, no significant differences in means can be found for certainty in environment A. In environment B there are significant differences found for landmarks 5, 15, 18 ($p < .05$), and 7 ($p < .01$). For all of these, the map users were more sure about their choice. However, when looking at the answers the participants gave on landmark recognition for these four landmarks, it can be seen that map users were not necessarily more correct (and certainly not significant better or worse, as described above) in their choice than device users.

For landmark certainty it is relevant to also compare means for route A and B and the total map and device groups; how sure a participant is about his choice can give information about the environment itself, where a higher certainty might indicate a higher legibility or better observable environment. No significant results can be found however for these comparisons of means (see table 4.6 and table 8 in appendix I), neither for the tests comparing means per environment.

Table 4.6 Mean scores for landmark certainty (maximum score is 5)

Route A, map (n=15)		Route A, device (n=15)		Route B, map (n=15)		Route B, device (n=15)		Total (n=60)	
Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
4.09	0.472	4.09	0.393	3.97	0.468	3.87	0.341	4.00	0.422
Paper map (n=30)		**Electronic device (n=30)**		**Route A (n=30)**		**Route B (n=30)**			
Mean	SD	Mean	SD	Mean	SD	Mean	SD		
0.62	0.104	0.61	0.101	4.09	0.427	3.92	0.406		

Relations

Furthermore, Independent Samples t-tests are performed to compare means of the certainty scores for correct answers with certainty scores of incorrect answers. This is done per experiment location, and in table 4.7 all significant results are shown. When the amount of participant per test does not add up to the total of 30, this is due to missing values.

Table 4.7 Results of Independent Samples t-tests comparing means of certainty for correct answers with certainty for incorrect answers (only significant scores are shown)

Route A				Route B			
	Sig.	Mean for yes (n)	Mean for no (n)		Sig.	Mean for yes (n)	Mean for no (n)
2. playground	.013	4.66 (29)	3.00 (1)	3. corner	.045	4.54 (24)	3.67 (6)
7. school	.006	4.59 (17)	3.17 (12)	12. significant house	.019	4.45 (20)	3.40 (10)
10. detail	.000	5.00 (4)	4.17 (24)	13. corner	.031	4.23 (26)	3.00 (4)
11. fake detail	.035	1.00 (1)	3.81 (27)	17. streetview	.004	4.08 (13)	3.06 (17)
13. corner	.006	4.30 (20)	2.88 (8)	21. corner	.047	4.38 (26)	3.25 (4)

What can be seen is that for these landmarks where t-tests reached significance, the mean certainty for a correct answer was higher than for incorrect answers (note that the answer for landmark 11 should be no). This indicates that participants giving correct answers were justly more sure about this. The landmarks that scored significant seem to be quite randomly spread over the different types of landmarks however, therefore no general conclusions can be drawn.

The correlation between mean landmark recognition and mean certainty per environment, as well as for all participants, has been calculated. Only for environment A this correlation reached significance ($p < .05$) with a coefficient of .388.

Different types of landmarks

The frequency graphs per landmark in appendix I show that participants answered quite different per landmark, even though there are almost no significant differences within the environments when compared for map and device groups. For some landmarks, almost all participants have recognized the location, for others almost no one did. In table 4.8 the mean scores for landmark recognition, divided for types of landmarks (see section 3.6.12) are given. It can clearly be seen that per type of landmark the mean scores are very different. The photographs of details of houses scored lowest for all experiment groups, and the highest recognition for route A is for the street views and for route B the corners where a turn was made.

Table 4.8 Mean scores for landmark recognition, per type of landmark

	Route A, map (n=15)		Route A, device (n=15)		Route A (n=30)	
	Mean	SD	Mean	SD	Mean	SD
Corners	0.68	0.240	0.77	0.176	0.73	0.211
Street views	0.80	0.185	0.84	0.172	0.82	0.177
Details	0.11	0.163	0.02	0.086	0.07	0.136
General landmarks	0.59	0.191	0.49	0.116	0.54	0.163
Fake photographs	0.77	0.258	0.77	0.258	0.77	0.254
	Route B, map (n=15)		Route B, device (n=15)		Route B (n=30)	
	Mean	SD	Mean	SD	Mean	SD
Corners	0.82	0.176	0.87	0.129	0.84	0.154
Street views	0.75	0.267	0.69	0.249	0.72	0.255
Details	0.07	0.138	0.11	0.241	0.09	0.194
General landmarks	0.63	0.167	0.67	0.163	0.65	0.163
Fake photographs	0.80	0.316	0.77	0.417	0.78	0.364

Independent Samples t-test showed no significant results when comparing the map and device groups per environment per type of landmark (see appendix I, table 9). When comparing mean scores per type of landmark between route A and B, significant results can be seen for corners and general landmarks ($p < .05$); indicating that route B participants performed better. This could mean that either the actual environment B is easier to remember, or that the photographs from environment B are not as hard to remember as those from environment A.

4.2.13 *Ordering photographs of intersections*

Participants are shown 9 photographs of street views and corners where a turn was made, and they have indicated the order they think the photographs should be in to match the order they saw the locations during their walk in the field. In order to check how well a participant scored, correlation coefficients are calculated between the participants' order and the correct order (the correct order can be found in appendix G: 'Correct solutions to tasks'). When the correlation coefficient is 1, the order of the participant is completely good, when 0 there is no relation at all, and when -1 the order is completely opposite to the actual order.

Before calculating correlation coefficients, the data are restructured so that each participant takes up 9 rows instead of 9 columns, in which the data are placed. The data for this task are ordinal, so instead of the Pearson Correlation the Spearman's Coefficient of Rank Correlation (Spearman's ρ) is used. Spearman's ρ is calculated for all different experiment groups, and shown in table 4.9.

Table 4.9 Correlations between actual and indicated order of photographs

	Spearman's ρ	Significance		Spearman's ρ	Significance
Route A, map (n=15)	.942	.000	Route A (n=30)	.904	.000
Route A, device (n=15)	.867	.000	Route B (n=30)	.754	.000
Route B, map (n=15)	.792	.000	Paper map (n=30)	.867	.000
Route B, device (n=15)	.717	.000	Electronic device (n=30)	.791	.000
All participants (n=60)	.829	.000			

First, what stands out is that for all groups the correlation is high and significant. Second, it can be seen that Spearman's ρ is higher for paper map users than for electronic device users; both for the total groups and when divided by environment. This indicates that the map users performed better in this ordering task than device participants. Furthermore is the correlation for route A higher than for route B. This can mean that either environment A was easier to remember, for example because the sights while walking the route were quite different from each other, or that for environment B more difficult photographs were used so that more mistakes were made.

4.2.14 *Placing photographs of intersections at the correct location on a map*

The scoring for this task has been done in a somewhat similar fashion as for the route drawing task. In appendix G: 'Correct solutions to tasks' a map of both environments can be found with the correct locations of photographs indicated. When the indication the participant made is located correctly, he is rewarded with 2 points. When the placement is approximately correct 1 point is given. Since there are 10 photographs to be placed, a maximum score of 20 (10 x 2) can be achieved. Scoring has again been done by both the experimenters. An example of scoring is given in figure 4.7.

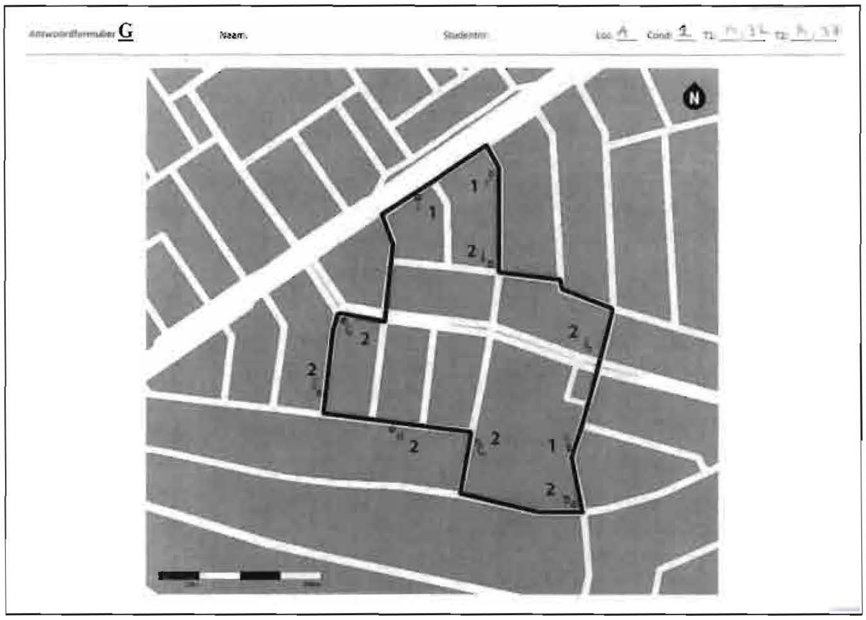


Figure 4.7 This participant received 17 points for the photograph placing task.

Placing photographs

Mean scores have been calculated and Independent Samples t-tests are performed to check for equality of means (see table 4.10 and table 10 in appendix I). None of the comparisons of means has reached a significant level, indicating that there are no differences in performances between groups.

Table 4.10 Mean scores for placing photographs on the map (maximum score is 20)

Route A, map (n=15)		Route A, device (n=15)		Route B, map (n=15)		Route B, device (n=15)		All participants (n=60)	
Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
14.67	3.222	14.20	2.957	14.13	3.777	13.93	2.939	14.23	3.170
Paper map (n=30)		Electronic device (n=30)		Route A (n=30)		Route B (n=30)			
Mean	SD	Mean	SD	Mean	SD	Mean	SD		
14.40	3.460	14.07	2.900	14.43	3.048	14.03	3.327		

Certainty of placing photographs

Furthermore, Independent Samples t-tests are performed to compare means of the certainty participants indicated for placement on the map (see table 4.11 and table 10 in appendix I). The only close to significant difference ($p < .1$) is the one between the two routes, indicating that participants in environment A are a little more sure about their placements. However, since this result is not significant, no conclusions can be drawn.

Table 4.11 Mean scores for certainty of placement on the map (maximum score is 5)

Route A, map (n=15)		Route A, device (n=15)		Route B, map (n=15)		Route B, device (n=15)		All participants (n=60)	
Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
4.16	0.403	4.05	0.456	4.03	0.563	3.73	0.533	3.99	0.506
Paper map (n=30)		Electronic device (n=30)		Route A (n=30)		Route B (n=30)			
Mean	SD	Mean	SD	Mean	SD	Mean	SD		
4.10	0.485	3.89	0.513	4.10	0.427	3.88	0.560		

Correlations

Correlation coefficients between the mean score on photograph placing and mean certainty, divided per experiment group, route and used aid are calculated. Results can be found in table 4.12.

Table 4.12 Correlations between photograph placing and certainty of this placement

	Pearson Correlation	Significance		Pearson Correlation	Significance
Route A, map (n=15)	.500	.057	Route A (n=30)	.560	.001
Route A, device (n=15)	.617	.014	Route B (n=30)	.441	.015
Route B, map (n=15)	.478	.071	Paper map (n=30)	.490	.006
Route B, device (n=15)	.417	.122	Electronic device (n=30)	.497	.005
All participants (n=60)	.489	.000			

For the two environments separately, as well as for the division per aid and for the total group of participants, a high and significant result is found. This indicates that correctness of placement and certainty about placement are highly related. The fact that correlations per experiment group almost never reach significance, is probably due to the small number of participants per group. Since a total score is used for the correct placement, no correlation coefficients can be calculated between the correct placement of a single photograph and the indicated certainty of this photograph.

4.2.15 *Questionnaire*

In the context of this thesis answers to this questionnaire are not analysed, since there is no direct link with the research question.

4.3 Relations of tasks with each other and the SBSoD self scale test

In addition to the analysis of the separate tasks in the sections above, possible relations between those tasks have been investigated. For the total or mean scores per tasks a correlation matrix is calculated and shown in table 4.13. Since no mean scores could be calculated for the ordering task, this task is not included in the matrix.

Table 4.13 Correlations between all analysed tasks

		1	2	3	4	5	6	7	8
1 Mean score SBSoD 1									
2 Mean score SBSoD 2	Pearson Correlation	.785							
	Significance	.000							
3 Mean absolute angular error of direction estimation	Pearson Correlation	-.233	-.260						
	Significance	.073	.045						
4 Total walking time	Pearson Correlation	-.163	-.106	.087					
	Significance	.214	.419	.508					
5 Score for route drawing	Pearson Correlation	.178	.216	-.202	-.278				
	Significance	.174	.098	.121	.032				
6 Mean of landmark recognition	Pearson Correlation	.038	.098	-.194	.263	.074			
	Significance	.775	.456	.137	.042	.576			
7 Mean certainty score for landmark recognition	Pearson Correlation	.278	.283	-.281	-.053	-.016	-.007		
	Significance	.031	.029	.029	.688	.903	.957		
8 Score for photograph placement on the map	Pearson Correlation	.164	.128	-.186	.003	.115	.199	.201	
	Significance	.211	.330	.155	.981	.381	.128	.124	
9 Mean of certainty for photograph placement on the map	Pearson Correlation	.354	.480	-.195	-.037	.153	.255	.311	.489
	Significance	.006	.000	.135	.779	.244	.049	.016	.000

Twelve relations reach a significant level (shaded in the table), and what can be seen is that especially the means of certainty indications correlate with many other tasks. Some of the correlations have already been found in the previous analyses (correlation between the two SBSoD tests and between the score for photograph placement on the map and certainty about this).

SBSoD self scale test

Between both the SBSoD tests and the two certainty indications (1 & 2 and 7 & 9 in the table) a positive correlation is found. This indicates that when a participant has a higher self reported sense of direction, that he is also more sure about his answers regarding landmark recognition and the placement of photographs on the map. However, this does not mean the participant is also better in the tasks, since there are no correlations found between the SBSoD tests and the actual scores for landmark recognition and photograph placement.

Furthermore, it can be seen that the correlation coefficients are higher for the relations with the second administration of the SBSoD test. A possible explanation for these higher coefficients is -even though we have seen in section 4.2.2 that there are no significant differences in mean between SBSoD 1 and SBSoD 2- that participants filled in the second SBSoD slightly more in relation to their feelings about certainty over the just performed tasks.

The same explanation may apply for the fact that there is found a significant correlation between SBSoD 2 and the mean absolute angular error of direction estimation and not for SBSoD 1. Note that even though the correlation coefficient is negative, it does mean that with a higher self perceived sense of direction participants perform better on direction estimation since error scores are used.

Certainty scores

Besides correlating with the SBSoD scores, the certainty scores also correlate with each other, indicating that a higher score on the one is related to a higher score on the other.

Furthermore it is remarkable that the certainty score for landmark recognition is not significantly correlated with landmark recognition, but that the certainty score for photograph placing on the map is.

On the other hand, no significant correlation is found between the mean certainties of photograph placing with the score for direction estimation, where the certainty score for landmark recognition does show correlation. This may be accidental.

Route drawing

There are two significant correlations where neither the SBSoD scores nor the certainty scores are involved. A negative correlation is found between the time of walking and the score for route drawing, indicating that a longer walk predicts a worse score on route drawing. Remember from section 4.2.5 that electronic device users needed more time to walk the route and from section 4.2.10 that these participants perform worse on route drawing. This explains the correlation between time of walking and the score for route drawing. For the correlation between total walking time and mean landmark recognition, a similar explanation may be valid.

4.4 Conclusion

In this chapter the performed data analysis is reported, and results are presented. There is decided that within the context of this thesis and based on the research questions asked not all gathered data are analysed. The fourth part (questionnaire one week after the walk) is totally excluded, and furthermore are the sketch map drawing tasks and the giving of navigation directions not analysed.

For each task, mean scores are calculated per experiment group (four groups: route A (map & device); route B (map & device)), and those means are compared with t-tests to check for their equality. Also, Pearson's and Spearman's correlations are calculated to check for correlation between tasks.

For some tasks scores had to be calculated or data had to be transformed before analysis could take place. The scores for route drawing and for placement of photographs on the map have been calculated by both the experimenters to reduce subjectivity.

It can be said that the group of participants is very homogenous. Besides a count of one third of females in each experiment group, there is a nice distribution of age (M = 21.1; SD = 4.0) and start year of the study. There are furthermore no differences between experiment groups regarding their self perceived sense of direction.

Both the administered SBSoD self scale tests are found to have a high internal reliability (Cronbach's α of .865 and .831) indicating that a total mean score can be calculated and used in other analyses.

In tables 4.14, 4.15 and 4.16 the found results from data analysis are summarised. An empty cell indicates that no significant result could be found, one asterisk (*) shows a significant result with

$p < .05$ and two asterisks (**) indicate a significance level of $p < .01$. What can be seen is that only a few of the performed tests showed significant differences or correlations. A plus sign indicates a result as expected, and a minus a result opposite to the expectation. This expectation is that paper map users will perform better than electronic device users. For the ordering task only a plus or minus is given since differences can be seen, but no *p*-value can be given.

Table 4.14 Differences in mean between paper map and electronic device users

	Route A	Route B
Direction estimation		
Walking time	* -	
Route drawing	* +	
Landmark recognition		
Landmark recognition certainty		
Photograph ordering	+	+
Photograph placing on map		
Photograph placing on map certainty		

For route A, the mean time of the walk was significantly longer for the device group (M = 00:17; SD = 00:01) than for the map group (M = 00:16; SD = 00:01). Since it was hypothesised that by taking away the work load for device users they would be faster, this finding is against expectations.

Furthermore, a significant result for comparison of means for the route drawing task in environment A was found. Map users performed as expected better (M = 19.2; SD = 1.5) than device users (M = 17.2; SD = 3.3).

To analyse the ordering task -where photographs of intersections had to be placed in the correct order- correlations are calculated (Spearman's ρ) between the actual order and the order as indicated by the participant. The correlation coefficients are higher for the map groups than the device groups in both environments (route A: .942 and .867; route B: .792 and .717). However, due to the method of analysis, no *p*-levels can be given.

Table 4.15 Correlations between task and certainty about this task

	Route A	Route B
Mean landmark recognition vs. mean certainty	* +	
Mean photograph placing vs. mean certainty	** +	* +

For the two tasks where is asked to indicate the certainty of answers, the correlations between these certainty scores and the scores for the actual tasks are calculated. For route A, both measures are significant and for route B only the correlations for photograph placing on the map. This shows that when the participant was more sure about his answer, he in general also scored better (or vice versa).

Table 4.16 Correlation between tasks and SBSoD self scale tests

	SBSoD 1	SBSoD 2
Direction estimation		* +
Walking time		
Route drawing		
Landmark recognition		
Landmark recognition certainty	* +	* +
Photograph placing on map		
Photograph placing on map certainty	** +	** +

In addition to the analysis of separate tasks, there is also tested for correlations between the tasks. Most interesting are the correlations found between the SBSoD test and both certainty scores, indicating that a higher sense of direction is related to a higher certainty about spatial tasks.

5

CONCLUSIONS DISCUSSION

5 CONCLUSIONS & DISCUSSION

In this chapter conclusions will be drawn, and an answer will be given to the research question. A discussion of results follows in section 5.2. Finally, recommendations for further research and the development of electronic navigation devices are provided.

5.1 Conclusions

The study presented in this report encompasses finding your way in an unfamiliar environment, and the amount of spatial knowledge that is remembered from this environment. The studied literature, as described in chapter 2, shows that there a several aspects that may influence this spatial knowledge acquisition. These can be characteristics of the individual, the environment or a used aid while experiencing the environment. This last aspect -and to be precise the difference between a paper map and an electronic navigation device- has been the key subject for the present study. The research question, as stated in the introduction, and the accompanying partial questions were therefore:

What is the difference in spatial knowledge acquisition between using a paper map and an electronic navigation device while navigating through an unfamiliar environment?

1. *How do people find their way?*
2. *How do people perceive their environment?*
3. *What is spatial knowledge?*
4. *How do people store spatial knowledge?*
5. *How can spatial knowledge be measured?*
6. *What are the characteristics of different types of navigation aids?*
7. *How can the influence of navigation aids on spatial knowledge acquisition be measured?*
8. *What is the effect of having more or less landmarks in an environment on spatial knowledge acquisition?*

Answers to the partial questions have already been found in the literature, and these are given in section 2.7. To be able to answer the research question, an experiment was designed and conducted.

In this experiment, participants walk a predefined route, thereby guided by either a printed paper map or an electronic navigation device. On both aids the route to be walked is shown. Two different environments are used to improve validity, and to be able to check for the influence of having more or less landmarks in an environment on spatial knowledge acquisition.

After walking the route, participants had to perform a series of tasks to measure their spatial knowledge of the experienced environment. Since almost none of the sixty participants had ever been at the experiment location before, it can be said that the knowledge the participant possesses of the environment is acquired during the walk.

The in the context of this thesis analysed tasks are listed below, with between brackets the type of spatial knowledge that is measured with the task:

- Direction estimation (orientation and survey knowledge)
- Drawing the walked route on a map (route knowledge)
- Landmark and intersection recognition from photographs (landmark knowledge)
- Ordering photographs of intersections (route knowledge)
- Placing photographs of intersections on a map (route and survey knowledge)

For the landmark recognition and photograph placing tasks, the participant also reported how sure they felt about the given answers.

It is hypothesised that participants using a paper map while navigating in the field will have gained more spatial knowledge than electronic device users, and as a result perform better on the different tasks measuring spatial knowledge. To test this assumption and thereby answer the research question, the answers from map users and device users are compared and checked for significant differences. This is done per environment, since differences that exist between the locations (either due to actual difference in the environment or due to the different implementation of tasks) should not affect the results.

For one of the analysed tasks -where the walked route had to be drawn on a map- significant differences are found for comparison of means between groups, indicating that paper map users performed better. This difference was however only found in environment A.

For the ordering tasks no significance indications can be given, but correlation analysis shows for paper map users a higher correlation to the actual order than for electronic device users. This result is found for both environment A and B.

For the other tasks, no significant differences are found between the performances of map and device groups. This indicates that the used aid had no influence on the answers to these tasks. It might however also mean that the tasks were not difficult enough or that the walked route was too easy or too short to make a proper comparison between map and device users.

Nevertheless, the results that are found indicate a better performance of paper map users over electronic device users. These results thus confirm the hypothesis. When looking at the type of knowledge that is measured with these two tasks -route drawing and photograph ordering-, it can be seen that for both this is route knowledge.

A possible way to explain why specifically this type of knowledge shows results, might be by looking back at the models of spatial knowledge acquisition by Stern and Leiser (1988; see figure 2.6) and Freundschuh (1992; see figure 2.8). It could be that no significant results were found for landmark knowledge and survey knowledge because participants acquired too much spatial knowledge to make a difference for the first, and too little for the latter. Or in other words; the tasks measuring landmark knowledge were performed equally well by map and device users, and the tasks measuring survey knowledge were answered equally poor. This would explain why on the tasks measuring route knowledge (with route knowledge standing in the middle between landmark and survey knowledge) a significant difference between paper map and electronic device users was found.

Landmarks

A new look can be taken at partial research question 8. To be able to answer this question, a look should be taken at the found differences between routes. It is however very hard to distinguish between found significant differences that can be traced back to the number of landmarks per route. Other aspects like the used landmarks, the clarity of photographs or the shape of the route may have caused differences. And even if the results are due to the used environments; this does not necessarily mean that the amount of landmarks made the difference, it could also mean that the environments are just not as comparable as thought.

For direction estimation significant differences are found between means for two of the pointing locations; where both environment A (more landmarks) and B (less landmarks) score better once. The route drawing task shows no differences between environments, nor does the photograph placing task. The landmark recognition task shows a significant difference between environments for two types of landmarks (corners and general landmarks), where higher means can be found for environment B. For the ordering tasks a higher correlation is found for location A. Given these contradictory indications, no answer can be given from this study to the question what the influence is on spatial knowledge acquisition of having more or less landmarks in an environment.

Other results

Next to results directly related to the research question, other interesting results are found. These concern the indicated certainty for having given the right answer to a task, and correlations between these certainty scores and the Santa Barbara Sense of Direction self scale test. For both landmark recognition and the placement of photographs does a higher certainty indicate a higher score on the task (and vice versa).

Both administrations of the SBSoD self scale test correlate with both certainty scores. The SBSoD tests however do not correlate with the sores for the actual tasks. So even if participants do not actually perform better, they are more sure about their answers when having a higher self perceived sense of direction.

5.2 Discussion

The fact that for quite some tasks no significant results are found might have to do with the implementation of the experiment. When more participants would be used, and maybe participants with a wider spread in age and background, stronger results may be found. Furthermore is the walked route maybe too short to cause big differences in spatial knowledge acquisition between experiment groups; it might simply be too easy to remember aspects of the environment. Also, because the speed of walking is not very fast, it might be the case that there was enough time to look around and absorb information from the environment for both the paper map and electronic device users. If the experiment would for example be performed by cyclists or drivers the results might therefore be more outspoken.

Furthermore, with hindsight, it could be the case that the two used environments and routes are not as similar as thought. This can for example be seen in the different amount of segments each route consists of (when all possible turning points are taken into account). Also, even though the environments are classified as being high or low in landmarks, this distinction is made more on feeling than on facts. Only when the amount of landmarks is varied systematically (in for example a virtual environment), an unambiguous distinction between many and few landmarks can be given.

Literature

A few aspects can be mentioned regarding the found results in the present study, and theories and results as documented in the literature. It should however be said that even though many of the performed tasks are similar to the ones performed in other studies, the differences between the two make them often impossible to compare. Many of them are for example more focused on *learning* an environment with use of different aids (Thorndyke & Hayes-Roth, 1982; Gale et al., 1990; and Willis et al., 2009), than on navigating through the environment over a predefined route.

The found significant difference in walking time between map and device users for environment A is against expectations, since device users are hypothesised to walk faster (Porathe, 2008; see section 2.5.2). It might however be the case that due to the inaccurate time recordings these findings under or overestimate the results.

The found correlation of the Santa Barbara Sense of Direction self scale test with direction estimation, is in line with findings in the literature; Hegarty et al. (2002) and Ishikawa et al. (2008) also found this correlation. The correlations between the SBSoD tests and indicated certainty about tasks is however a new finding.

5.3 Recommendations

A first obvious recommendation that can be made is to analyse all the data gathered with the experiment. The drawn sketch maps are for example a large source of information, and when analysed it is expected that significant differences between map and device users can be found. Furthermore, the data from the second administration of the questionnaire, one week after the field experiment, will possibly give information about how spatial knowledge decays over time, and the influence of the used navigation aid during the walk on this decay.

For investigating the effects of having more or less landmarks in an environment on spatial knowledge acquisition, it might be a good idea to test this in a virtual or controllable environment. Even though an actual setting will give more life-like experiences for participants, by using a virtual environment it can be made sure that environments (and the route in it) are the same, except for the (amount of) landmarks.

Furthermore it might be interesting to test for other navigation aids than used in the present study, or to vary with settings. It could for example be expected that when a 3D setting on an electronic devise is used during navigation, other results are found than in the present study. This also applies for the used tasks and the exact way they have been administered. When adaptations are made it might be possible to get more significant results.

Besides contributing to the existing body of knowledge on environmental psychology, a second goal of this study was to give suggestions regarding the improvement of electronic navigation aids. The found results however do not lead to very specific recommendations. In combination with findings from the literature study, there are however a number of aspects that should be kept in mind by developers of electronic devices.

Firstly, more 'overview' of the environment a user is navigating through might stimulate the development of the cognitive map and higher forms of spatial knowledge. By integrating this feature in electronic devices it will be easier for the user to oversee the spatial information and put it in perspective. However, since display sizes are in general quite small, it might prove to be difficult to do so.

What possibly also can help in the stimulation of spatial knowledge acquisition is to keep the user of an electronic navigation device 'in the loop' by engaging him in the process of finding his destination. However, most people use a device for precisely the opposite: to eliminate the planning process and the thinking about the route to be followed. Therefore, it will be necessary to keep the navigator engaged in a discrete way so that he does not realise that he is being tested.

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"Looking at cities can give a special pleasure, however commonplace the sight may be. Like a piece of architecture, the city is a construction in space, but one of a vast scale, a thing perceived only in the course of long spans of time. [...] At every instant, there is more than the eye can see, more than the ear can hear, a setting or a view waiting to be explored. Nothing is experienced by itself, but always in relation to its surroundings, the sequences of events leading up to it, the memory of past experiences."

Kevin Lynch, 1960