TECHNISCHE UNIVERSITÄT WIEN

MASTERARBEIT

Investigating the effects of mobile navigation services and paper maps on the spatial knowledge acquisition of pedestrians in an indoor environment

zur Erlangung des akademischen Grades

Master of Science

im Rahmen des Studiums

Cartography

eingereicht von

Julius Nyonyo

Matrikelnummer 11939459

ausgeführt am Institut für Geodäsie und Geoinformation der Fakultät für Mathematik und Geoinformation der Technischen Universität Wien

Betreuung
Betreuer: M.Sc. Wangshu Wang (TUW)

Vienna, 10.10.2021 _____ _____

Unterschrift (Verfasserin) Untershrift (Betreuer)

MASTER THESIS

Investigating the effects of mobile navigation services and paper maps on the spatial knowledge acquisition of pedestrians in an indoor environment

For the Achievement of the Academic Title

Master of Science

Within the Degree Course

Cartography

Submitted By

Julius Nyonyo

Student ID 11939459

Completed at the Department of Geodesy and Geoinformation of the Faculty for Mathematics and Geoinformation at the Technical University Vienna

Supervision
Supervisor: M.Sc. Wangshu Wang (TUW)

Vienna, 10.10.2021 _____ _____
Signature (Author) signature (Supervisor)

Cartography M.Sc.

Master thesis

Investigating the effects of mobile navigation services and paper maps on the spatial knowledge acquisition of pedestrians in an indoor environment

Julius Nyonyo

Technical University of Munich

TECHNISCHE UNIVERSITÄT WIEN Vienna University of Technology

TECHNISCHE UNIVERSITÄT DRESDEN

ITC UNIVERSITY OF TWENTE.

2022

Investigating the effects of mobile navigation services and paper maps on the spatial knowledge acquisition of pedestrians in an indoor environment

submitted for the academic degree of Master of Science (M.Sc.)
conducted at the Department of Aerospace and Geodesy
Technical University of Munich

Author: Julius, Nyonyo
Study course: Cartography M.Sc
Supervisor: M.Sc. Wangshu Wang (TUW)
Reviewer: MSc. Bing Liu (TUM)

Cooperation: if applicable

Chair of the Thesis
Assessment Board: Univ.Prof. Mag.rer.nat. Dr.rer.nat. Georg Gartner,TUW

Date of submission: 17.06.2022

Statement of Authorship

Herewith I declare that I am the sole author of the submitted Master's thesis entitled: **"Investigating the effects of mobile navigation services and paper maps on the spatial knowledge acquisition of pedestrians in an indoor environment"**

I have fully referenced the ideas and work of others, whether published or unpublished. Literal or analogous citations are clearly marked as such.

Vienna, 17.06.2022 Julius Nyonyo

ACKNOWLEDGEMENT

My first thanks goes to God for His mercy, grace, favour and blessings upon me and for giving me life and strength to go through all my daily activities.

My sincerest appreciation goes to Erasmus Mundus and other programme partners for making it possible for me to enroll in this rewarding course. I am sincerely grateful to them for everything – the sponsorship to be able to complete this programme in Europe.

I cannot thank Juliane Cron (the programme coordinator) enough for what she has done for us: not only me, but what she has done for the entire 9th Intake. Very kind and loving individual who tirelessly took care of us and handled us like her children. The MSc Cartography 9th Intake was blessed to have you.

To my dear Supervisor, Wangshu Wang, you were a blessing to me. You supported me in every angle and never gave up on me. I sincerely thank you and it is my prayer that you achieve whatever your heart desires.

I cannot leave Prof. Georg Gartner out. A very free-spirited person who chaired the Research Division Cartography, TU Wien and made sure that research works are duly completed to its best.

I am also grateful to all my colleagues from the 9th Intake who supported me in one way or the other, especially Sadhman Sadik (just like a brother to me) who was selflessly very helpful throughout my master's study period.

Lastly, my appreciation goes to my family and also to my friends who helped me during the data collection process.

I really appreciate you all and thank you again for making this journey of my life a success.

Table of Contents

List of figures

List of tables

Chapter One

INTRODUCTION

1.1. Background

Navigation is an everyday activity of human life. It could occur on the sea, the land, and in the air. There are number of ways to define navigation, but in a simple term, navigation could be described as the art and science of finding locations. Nowadays, navigation is mostly done by the help of navigation aids. These navigation aids are seen as crucial equipment that reduce human efforts in finding precise location of places. Paper maps and mobile maps, for example Google maps, are good examples of navigation aids. On daily basis, people use one of these tools to find their ways out in either indoor or outdoor environments. Finding one's way to a particular destination is a planning process. For example, using landmarks for orientation and decision-making (Montello, 2005). The aim to maximise time is by finding their destinations with ease, hence the need for navigational aids in this present times. For the purpose of this study, the researcher considers paper maps (PM) and mobile navigation services (MNS). Paper maps are spatial representations drawn on paper to depict the real world. They are mostly printed or hard copy maps. Mobile maps are electronic maps which also represents spatial features. Unlike the paper maps, mobile maps are softcopy maps. In terms of user-relations, mobile navigation services require less attention from the user while paper maps require more attention. Unlike paper maps, mobile navigation services require the use of internet, battery life (power) and relatively smaller display size.

For navigational tasks, acquiring spatial knowledge is crucial to orient and navigate in space without losing the way. Navigation system is seen as a very important need to pedestrians. Despite this importance, research has shown that this form of passive navigation does not help pedestrians to become familiar with their environments or keep in memory the landmarks in their surroundings (Ishikawa et al., 2008, Kyoko & Veronique, 2013, Eleanor et al., 2000). Acquiring spatial knowledge is very important, because if the navigation system fails, navigators have to rely on their acquired knowledge to find their locations.

Kyoko and Veronique (2013) revealed in their study that when people's navigation skills are reduced, there is decline in their intellectual abilities especially during old age. Other researchers (Münzer et al., 2006, Ishikawa et al., 2008) on the other hand have found that navigating unknown

environments by the use of paper maps helps navigators to become more familiar with the environments than mobile navigation services. Map based automated navigation can also have negative effect on spatial transformation abilities, especially with respect to changes in perspective, and environmental learning (Parush, Ahuvia, & Erev, 2007). Despite the popularity of navigation systems, concerns have been raised in literature about the negative effects it has on spatial knowledge acquisition because of its extensive use. These systems consume most pedestrians' attention, leading to decreased spatial knowledge (Parush, Ahuvia, & Erev, 2007). Unlike paper maps, mobile navigation services automatically selects and depicts environmental properties (e.g. landmarks) without any user intervention, which leads to decreased attentiveness to relevant properties (Taylor, Brunyé, & Taylor, 2008). Other studies have also shown that automated guidance divides a navigator's attention between the navigation system and the environment (e.g., Gardony et al., 2013, Ishikawa et al., 2008). From previous research (Münzer et al., 2006, Ishikawa et al., 2008, Gardony et al., 2013, Taylor et al., 2008, Parush et al., 2007), differences in map media, for example paper maps and mobile navigation service could influence spatial knowledge acquisition of users. However, this evidence was from studies conducted in the outdoor environment. How about the indoor environment? Could the findings be the same in the indoor environment? Most of these studies (Münzer et al., 2006, Ishikawa et al., 2008, Gardony et al., 2013, Taylor et al., 2008, Parush et al., 2007), focused on outdoor environment, but indoor environment is also important (Delazari et al., 2018). Indoor environment, unlike the outdoor environment, basically depicts enclosed interior of buildings above the ground and spaces underneath the ground that afford platforms for human activities. Several factors differentiate the indoor environment from the outdoor environment. According to Yang and Worboys (2011), scale and dimension, geometry and topology, positioning technology, landmarks, navigation agents and routing information are those categories where indoor and outdoor environments could be differentiated. For example, for navigational purposes, agents in outdoor environments could be either pedestrians or vehicles whereas agents in the indoor environment are mostly pedestrians (Guidice et al., 2010). With respect to landmarks, both distant and local landmarks are recognizable in the outdoor environment, but in the indoor setting, landmarks are generally local ones, because corners and walls of the building block pedestrians' visions.

Owing to the differences in the outdoor and the indoor environment, the question is, how different could paper maps and mobile navigation services affect the efficiency of movement and spatial knowledge of map users in the indoor environment? Taking this curiosity into consideration, this research is geared towards investigating the effects PM and MNS post to pedestrians' movement efficiency and their memory skills in memorizing spatial features in the indoor setting.

1.2. Research Identification

1.2.1. Research objectives

The main objective of this research is to explore how paper maps and mobile navigation services influence navigation and spatial knowledge acquisition mainly in an indoor environment. In order to systematically achieve this overall aim, the researcher subdivided the main objective into two specific objectives. These are to explore;

1. The efficiency of pedestrian navigation with paper map and mobile navigation services.
2. The influence of paper map and mobile navigation service on spatial knowledge acquisition.

1.2.2. Research questions

The following research questions will aid the researcher in achieving his objectives;

1. How do paper maps and mobile navigation services affect the efficiency of pedestrian navigation?
2. How do paper maps and mobile navigation services influence the spatial knowledge acquisition of pedestrians?

1.2.3. Research hypotheses

The following hypotheses were formulated by the researcher for further testing.

i) Navigating with mobile navigation services is more time efficient than paper maps.

ii) Pedestrians who use paper map to navigate once can navigate faster than those who used mobile navigation services.

iii) Paper map enables better spatial knowledge acquisition than mobile navigation services.

1.3 Significance of the study

Navigation is an important activity of human life and as such, research in this field is on the rise. The relationship between paper maps, mobile navigation services and spatial knowledge acquisition has been a field of major interest. Most of the researchers delved into this field of

research interest, but they mostly considered the outdoor environment. This study is designed to research into similar themes, but at this time in the indoor environment. The essence of this research is that it will contribute or add to existing literature on spatial knowledge acquisition and navigation assisted maps. This work will also serve as a source of extended knowledge in the field of Cartography and navigation. In the future, researchers can have access to more literature for their works.

1.4 Scope of the study

The scope of this study is classified into thematic scope and geographic scope. With the thematic scope, the work tries to look at the relationship between assisted navigation tools (maps) and spatial knowledge acquisition in the indoor environment. Geographically, the experiment of this study was undertaken in the Centrum Galerie of Dresden, Germany. There researcher did not consider any other scope apart from the aforementioned ones.

Chapter Two

LITERATURE REVIEW

2.1. Introduction

This chapter contains relevant literature which is based on two themes: the two objectives of the study. The chapter also considers defining key terms which have been defined by previous researchers and need to be critically understood for the purpose of this research and also bringing to light some related works. The two themes of the study is sub-divided into four categories. These are; the efficiency of navigation with paper maps, the efficiency of navigation with mobile navigation services, spatial knowledge acquisition with paper maps and spatial knowledge acquisition with mobile navigation services.

2.2. Definition of key terms

Key terms that are of relevant to the researcher and need to be critically understood are; mobile navigation services, paper map and spatial knowledge acquisition. These words will be frequently be used and need to be well understood for the purpose of this work.

2.2.1. Mobile navigation services

One of the most frequent terms used in this research is Mobile Navigation Service (MNS). This is one of the most important applications of location Based Services (LBS) and it is mostly used for finding locations (Mihai et al., 2009). Mobile navigation services are also digital maps which are used on phone and also needs to be connected to a wireless network before in use. In this research, mobile navigation service is seen as a digital map which is operated on a phone to suggest routes for finding locations of spatial features. According to Chu et al (2017), Mobile navigation services can differ in scale, content, and style. As a result, the effectiveness of different types of maps for indoor route communication should be evaluated. Google Maps are good examples of mobile navigation services.

2.2.2. Paper maps

Aside mobile navigation services, another term that is of importance to the research is paper map. Paper has been the format of choice for disseminating geographic information for millennia; however the arrival of the internet and mobile technologies has created new modes of map

consumption (Hurst & Clough, 2013). Like the mobile navigation services, paper maps are also used for finding locations. However, paper maps are simple maps and are limited to a specific area based on scale – that is they are maps that are representations of spatial features on a limited area and not the entire geographical location (Dhar & Chanda, 2006). Also, according to Reilly et al, (2006), Paper maps are printed maps and are interesting real world artifacts to augment in part because they are themselves an information resource. To them, examples could be an Atlas or a fold-out paper on which a map is drawn. In this research work, paper maps are defined as hardcopy or printed maps showing spatial representation which are mostly drawn to scale.

2.2.3. Spatial knowledge

Space is one of the basis or fundamentals of geography. In geography, space can be seen as a location or geographical point on the surface of the Earth which are defined by longitude and latitudes. In practice, learning about space can be seen as a way of acquiring spatial knowledge (MacEachren, 1991). People generally acquire environmental spatial knowledge through direct experience by locomoting through an environment or by viewing a map (Richardson et al., 1999).

Kinds of spatial knowledge have been distinguished on the basis of the spatial extent of features (point, line, and area), the function that those features might have for environmental behaviour (e.g. landmark, node, path), and the level of cognitive processing required (MacEachren, 1991). Also, there are three levels of spatial knowledge: active space, perceptual space and symbolic space (Cassirer, 1944: cited in Alexander & Sheldon, 1975). Active space are the temporal co-occurrences that make it possible for object manipulation and coordination. Perceptual level allow for the assembly of routes and maps of spatial representations. The third level (symbolic space) is the development of symbol systems for the construction and arrangements of line and space.

In this study, spatial knowledge could well be seen as the information about the locations of geographic phenomena in a geographic zone at a particular period of time. The process of learning about the locations of geographic phenomena could also be termed as spatial knowledge acquisition.

2.3. Related Work

A handful of research have delve into studying how maps affect spatial knowledge comparing different modalities or devices. For example, in the work of Münzer et al (2006), they compared paper maps with navigation systems and have found that pedestrians who use paper maps show

better spatial knowledge acquisition more than those who use the navigation system. They further asserted that though paper maps help in acquiring good spatial knowledge, it lowers navigation performance of pedestrians compared to using the navigation system in terms of longer duration to destination. Ishikawa et al (2008) also conducted similar research and they found out that modern digital navigation systems have a negative impact on the formation of mental spatial representation, but people using this navigation system are more time efficient and effective in finding their locations quickly than those using paper maps.

Both research were conducted and revealed the same result which is a way of ascertaining and confirming knowledge. However, both research were performed in the outdoor environment. These early attempts in exploring the effects of technology assisted navigation and paper maps on spatial knowledge acquisition have not so far produced results that can lead to practical advice in the indoor environment, hence the need for this research.

2.4. The efficiency of navigation with paper maps

Efficiency is the accomplishment of or the ability to accomplish a job with a minimum expenditure of time and effort (https://www.dictionary.com/browse/efficiency). With respect to this definition, the main reference to efficiency in this research is *time*. In every activity we as humans execute, we aim at maximizing time in order to achieve the best output. The efficiency of navigation is of immense importance to the researcher and this the researcher decided to investigate. Do paper maps help in efficient navigation? Previous researchers (Münzer et al., 2006: Hergan & Umek, 2017) in their studies asserted that navigating with paper maps is not as fast as navigating with mobile navigation services. However, they also gave the nod to paper maps as the best when it comes to learning and acquiring spatial knowledge in the environment.

Other studies (Smets et al., 2008: Schöning et al., 2009) also considered the fact that paper maps are of immense importance in navigation irrespective of how slow it takes to help you get to your destination.. In their studies, they concluded per their findings that even if the field of navigation is pointing to the use of mobile navigation services, there are a lot of folks who still prefer the use of paper maps to navigate than mobile navigation services. Hergan & Umek (2017) reported in their study that some people prefer the use of paper maps to mobile navigation services for navigation because to them, paper maps can be used almost everywhere unlike mobile navigation services. This is because there are places where GPS signals do not work and in this case, mobile

navigation services could not been of use, but rather, paper maps could solve the navigation issue at this juncture. In this regard, in their study, they considered paper maps to be the fastest for navigating in any environment unlike other researchers (Münzer et al., 2006: Hergan & Umek, 2017) who accepted mobile navigation services as the best tool for fast navigation. Ideally, there some people who also believe that since paper maps do not require signal and battery, they are the best tools for smooth navigation without fear of power outage or signal break (Besharat et al., 2016). There is something good about paper maps, especially in navigation. Unfolding and laying maps flat on a table, you get to see the size and perspective that is actually lacking when you look on a smallish screen or wait for the voice to tell you when to make the next turn (Besharat et al., 2016).

Intuitively, we think that mobile navigation services make less distraction while driving. Likewise, we also think that computer-optimized navigation can get us to our destinations faster than paper maps. Contrary to this, in the research conducted by Ishikawa et al (2008), a renowned specialist in human spatial behaviour, and his crew asserted that relying on digital directions can slow you down compared to plotting an analog course. Dr. Toru Ishikawa and his crew also found out that people who depend on GPS to find their ways out on foot, walk slower, made more direction errors and ultimately take them longer time to reach their destinations compared to people who depend on paper maps or who were shown the route to take on a map beforehand. To them, interacting and with the map and having more information about the environment you navigate, makes you move faster and reach your destination quickly. Per the findings of these researchers, paper maps are the fastest in terms of navigating a route or finding locations.

2.5. The efficiency of navigation with mobile navigation services

There are digital aids such as the mobile navigation services (e.g. Google Maps) to improve people's skills of travel and navigation. Teaching young generation how to access the needed technology, utilize the knowledge needed in using these navigation tools or app and helping them to make decisions on information obtained can help posterity navigate the complex environments such as big cities and colleges (McMahon et al., 2015). McMahon et al (2015) have identified in their research that mobile navigation services are the safest and the easiest tool to use when it comes to navigation. Their assertion was based on the fact that there are not too much human influence in deciding routes to take to locate destinations, but rather, mobile navigation system depends on the use of the Global Positioning System (GPS) which make navigation quick and faster. To this researchers, mobile navigation services have been the best form of assisted navigation since the

dependency on GPS makes movement accurate and faster with less human effort in deciding their own navigation routes.

Erev (2007) also concluded that mobile navigation services help in completing or finding locations faster than paper maps, but the only disadvantage of it is that it hinders privacy.

In the research of Chu et al (2017), they found out that GPS directions can be misleading and can navigate you to unnecessary routes before reaching your desired location. Despite its enormous adoption in the world, it sometimes fail in pointing you in the right direction to your destinations. Most especially, GPS misleading happens in the rural areas and this has made the use of mobile navigation services in some typical rural areas as totally unacceptable. Chu et al (2017) saw paper maps as the best tool to use to navigation these typical rural regions for faster movement and efficient use of time.

From literature, the use of mobile navigation services has been accepted by majority of people with respect to navigation. Some people see it to be the safest and the fastest tools that directs and guides pedestrians to their destinations with ease. However, there are also some concerns been raised against mobile navigation services irrespective of how fast it guides pedestrians to their destinations. The issue of mobile navigation services infringing on the privacy of people made it unacceptable by some group of people and hence these group of people resort to using paper maps other than mobile navigation services. Aside this, in typical rural environment where internet and power become a problem, the use of mobile navigation services could be unlikely and thereby making mobile navigation services unreliable.

2.6. Spatial knowledge acquisition with paper maps

The ability to navigate an environment with your own instincts, well-earned acumen, observed orientation and perception is something that has been in practice for over thousands of years. This kind of navigation makes navigators own the process and makes navigation active. This also makes people to have good interaction with their environments. Analog navigation is not only satisfying, but it gives you a sense of confidence and makes you feel like owning your environment (Besharat et al., 2016). Relying on paper maps for navigation means that you will have to pay attention to your environment in order to make sure that you are moving on the right path to your destination.

Paper maps give you or make you aware of the environment you are in, where you are going or where you have been. It gives you a clear picture of the spatial features in your environment and thereby making you to acquaint yourself with the landmarks and make concrete decisions in terms of planning and movement. Ishikawa et al (2008) found in one of their studies that paper maps are the best maps when it comes to getting acquainted with your environment and learning more about the environment in order to acquire more spatial knowledge. To them, paper maps are easy assets to acquiring enough spatial knowledge of your environment. Similar assertion was made in the findings of Chu et al (2017). They concluded in their research that anyone who has the urge to learn about their environment should consider using paper maps. Their assertion confirm the fact paper maps are good tools for obtaining spatial knowledge of one's environment.

Taking insight from literature, the use of paper maps for navigational purposes is the best way if every individual seeks to learn about their environments. It makes it easy to memorise landmarks and keep the location and position of the spatial features in the environment.

2.7. Spatial knowledge acquisition with mobile navigation services

Pedestrian navigation with GPS has become increasingly popular (Gartner, 2016). You may have no idea of where you really are if you use GPS for navigation. The north, south, east and west all become meaningless – this is because you are just following discrete directions. Navigating with mobile navigation service is like you spend the whole navigation period looking at your feet (Chen & Li, 2020) it makes you a passive navigator without having to decide for yourself.

Inasmuch as navigating with mobile navigation services is faster as compared with paper maps, there are occasions where people, as a result of relying on mobile navigation service, run or drive into rivers and lakes because these people over relied MNS at the expense of their own senses (Chen & Li, 2020). The more people depend on mobile navigation services, the more they lose their spatial awareness.

The reasons why some group of people prefer to use paper maps to mobile navigation service are yet to be confirmed. However, some studies (Hurst & Clough, 2013: Dhar & Chanda, 2006) are suggesting that the reason for preference of paper maps to MNS is that over reliance on mobile navigation service may increase memory loss and thereby prevent ability to think and learn things about our environments Willis et al (2009) in their study found that relying on GPS does not only reduce our memory recall of the environment, but it can also destroy our ability to undertake future

planning. Mobile navigation services for navigation may reduce user's self-navigation ability (Edler et al., 2019, cited in Liu et al., 2021) and make them prone to losing their mental ability to memorising landmarks in the environment. In the work of Chen & Li (2020) on spatial knowledge acquisition with mobile maps, they found that mobile maps are essential and easy tools for navigation, but they do not actually help the navigator to acquire enough spatial knowledge of their environments.

The main key for finding solution to spatial problems depends on whether a person can effectively and efficiently acquire spatial knowledge – that is trying to form an optimal spatial environmental representation. Literature have actually shown that navigating with mobile navigation services can reduce the spatial cognition of people and thereby hindering them to learn more about their environments. Once you depend on a navigation app to navigate, you pay less attention to your surroundings and this prevents you from making efficient and effective navigation decisions and thereby making you a passive navigator. Navigating with GPS or any mobile navigation service, you do not gain complete knowledge of your environment, but rather, you become a dependant on technology. This could easily drain your memorising skills you need to navigate on your own.

Chapter Three

RESEARCH METHODOLOGY

3.1. Introduction

The methods or steps the researcher is to follow for a successful completion of this research is outlined in this section. The section will comprise of a brief description of the project set-up, study area, selection of experiment participants, procedure of experiment and method of data analysis.

3.2. Project setup

This thesis is divided into five chapters. Chapter one contains the general introduction to the research topic including the research objectives, questions, hypothesis and the significance of the study. A review of existing literature is conducted and presented in chapter two. Research methodology is captured in chapter three. The results from the research experiment and the questionnaire used for the survey are collated, presented and analysed in chapter four. Chapter five, which is the final, contains summaries, discussion and conclusions. The projected completion date for this research is 17th June, 2022.

3.3. Study area

The researcher's aim was to select a study zone which has not been visited by survey participants. The reason for this is to enable the validity of the experiment and the research as a whole. The Centrum Galerie was the choice of the researcher. This study area is located in the north of the city Dresden *Seevorstadt* Germany. It is a shopping mall and also have some offices. It is bounded by Prager Strasse to the east, Waisenhausstrasse to the north and Reitbahnstrasse to the west.

3.4. Selection of participants

The study consists of 20 participants. Owing to the popularity of the study zone in Dresden, the researcher considers selecting participants who reside outside Dresden. For example, people who reside in neighbouring cities (Freiberg and Leipzig) of Dresden. This action was taken due to the fact that residents of Dresden might have already visited and have full knowledge about the study area which could further hinder the validity of the study. Therefore, selecting people outside of

Dresden and who have not visited the study area before will be a good way of making this research valid.

Identifying and selecting these category of participants will be done through the help of some friends in Freiberg and Leipzig. The researcher will then administer a pre-selection questionnaires to the participants to obtain their demographic characteristics and also to identify and select those of the people who have not visited centrum Galerie before.

3.5. Procedure of experiment

This section of the study enumerates the procedure of the research experiment. It is further sub-divided into three: 1) *grouping and sampling* which contains the method use in sampling participants and the order of how participants are taken for the experiment one after the other, 2) *navigation exercise* contains how the navigation experiment is carried out and 3) *test for spatial knowledge* contains the three methods (pointing task, landmark recognition and estimation of landmark locations) used for testing the spatial knowledge of the participants.

3.5.1. Group formation and sampling

All the selected participant were clustered into two groups. The formation of these groups was done according to the maps (paper map and mobile navigation services) of interest for this research. PM represents the paper map group and MNS represents the mobile navigation group. See figure 1 for clustering and sampling of participants.

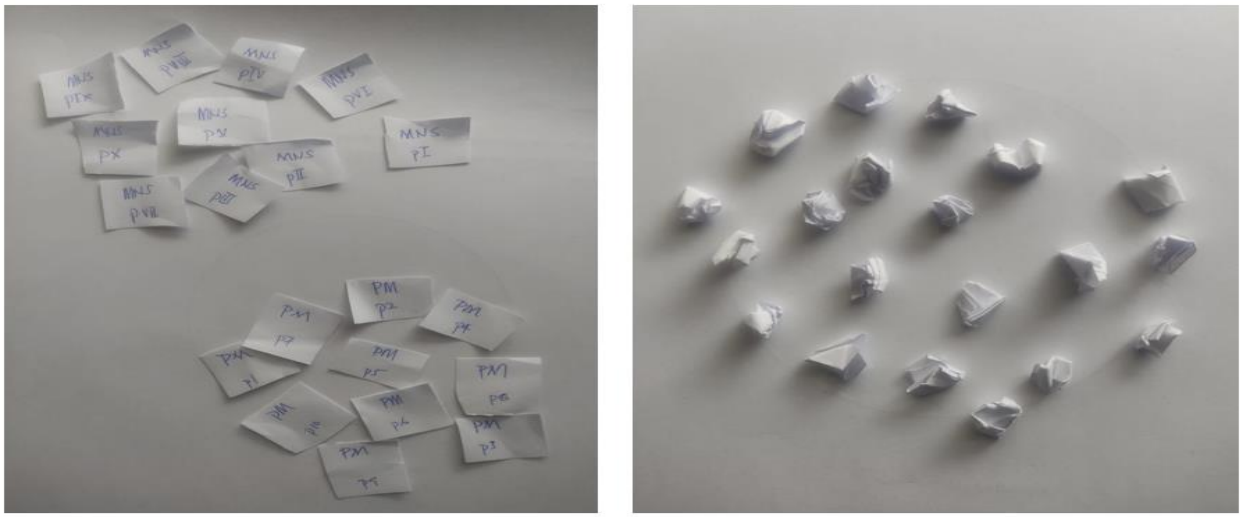


Figure 1: ***clustering and sampling of participants***

Source: ***Julius Nyonyo, 2022***

For participant clustering and sampling, the group names (PM, MNS) together with participants' ID numbers were written of pieces of papers and wrapped. Each survey participant was to pick a piece of paper to reveal the group he or she belongs to and also his or her ID number. In all, there will be 10 apiece in each group.

3.5.2. Navigation exercise

The navigation exercise was conducted for the two groups on the same day. There was a toss of coin of which group performs the experiment first and PM group came out as the first group to perform the experiment.

In terms of route selection, the researcher selected the routes such that there will be multiple turns in order not to have simple straight route. The points of interest and the direction of the route is from: 1) *Eiscafe* 2) SportScheck 3) *L'OCCITANE* 4) *Marc O'Polo* as shown in figure. 2.

During the navigation exercise, each participant navigates from the starting point (i.e. *Eiscafe*) through *SportScheck* and *L'OCCITANE* to the ending point (*Marc O'Polo*) with their respective maps – that is an assisted route-following task and then retreats from the ending point to the starting point without maps – use of spatial knowledge during route-reversal task (Brugger et al, 2019).

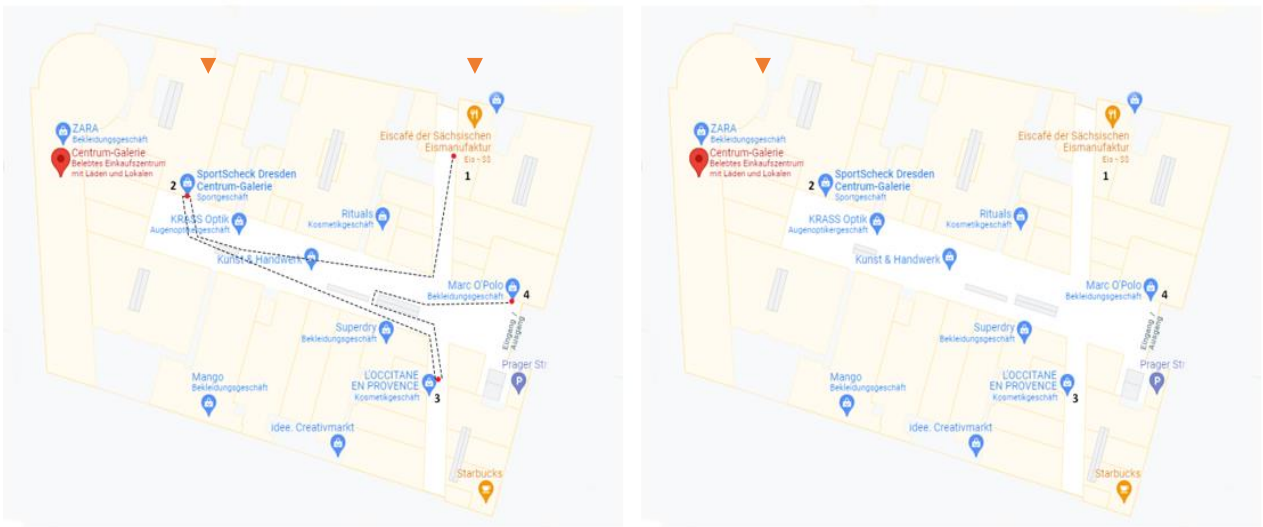
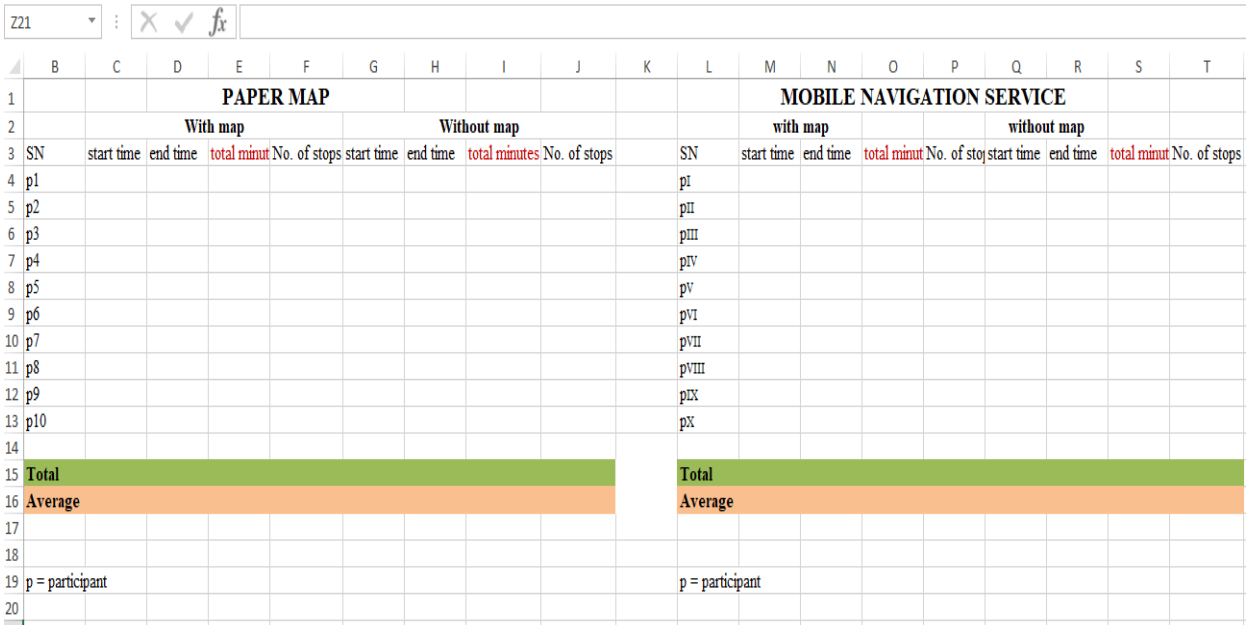


Figure 2: ***Route maps for MNS and PM groups in Centrum Galerie respectively***

Source: ***Julius Nyonyo, 2022***

For the MNS group, there is a predefined route that was suggested by the Google Maps. With this, participants in the MNS group will have to follow the route suggested by Google from the starting point to the ending point. On the other hand, that is for the paper map, there is no predefined route and therefore, participants in the PM group will have to find their ways out from the starting point to the ending point.



	PAPER MAP										MOBILE NAVIGATION SERVICE									
	With map					Without map					with map					without map				
	SN	start time	end time	total minut	No. of stops	start time	end time	total minutes	No. of stops		SN	start time	end time	total minut	No. of stop	start time	end time	total minut	No. of stops	
	p1										pI									
	p2										pII									
	p3										pIII									
	p4										pIV									
	p5										pV									
	p6										pVI									
	p7										pVII									
	p8										pVIII									
	p9										pIX									
	p10										pX									
	Total										Total									
	Average										Average									
	p = participant										p = participant									

Figure 3: ***Experiment record sheet***

Source: ***Julius Nyonyo, 2022***

Figure 3 shows the worksheet for the experiment. Record is entered for PM group and MNS group. The section for each group is divided into 2 parts: "*with map*" and "*without map*". The researcher use this and then record the start – end time, total minutes and number of stops for every participants in each group. The total and average values were also recorded for further analysis.

3.5.3. Test for spatial knowledge

The following three methods were used to test the spatial knowledge of the participants. The first approach used was the pointing task which was performed by each participant immediately after he or she reached the endpoint of the navigation route. Pairing images was also used and estimation of landmark locations.

3.5.3.1 Pointing task

One of the 3 methods used for testing the spatial knowledge acquisition of participants was the pointing task. In this method, participants were to draw a line from the center of the circle to the circumference indicating the direction to the starting point of the navigation route. The standing point for drawing this line is the end point of the navigation route. There is an original *angle* that will be measured by the researcher using a mathematical instrument called the "protractor". The angle drawn by the participants called the *participant angle* will be measured and recorded. Then, *angle difference* is measured by subtracting the value of the participant angle from the original angle. The difference in angle will be further used for analysis. See figure 4 for the template.

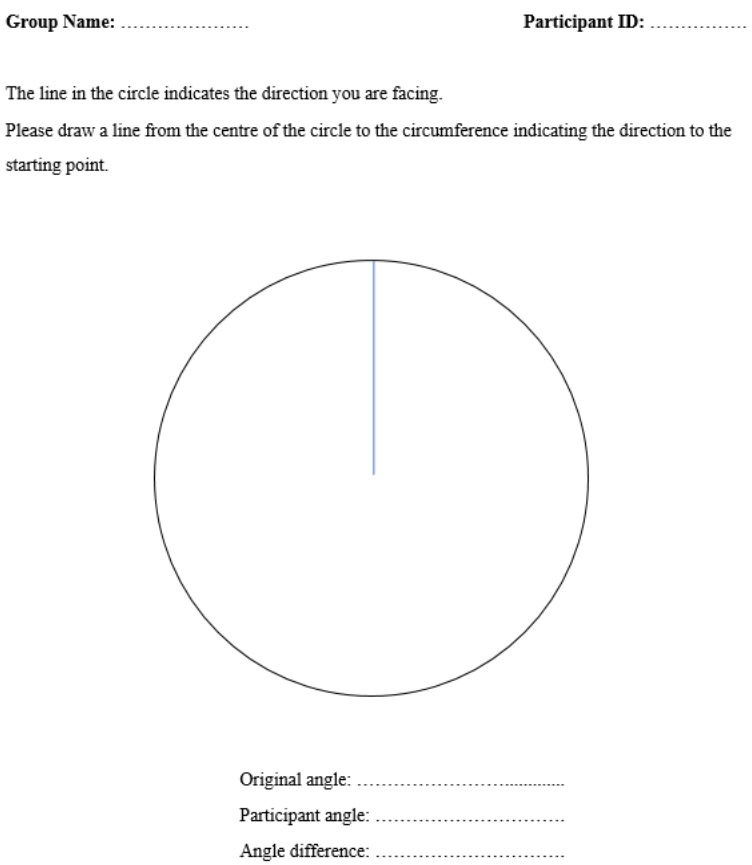


Figure 4: ***pointing task template***

Source: ***Julius Nyonyo, 2022***

3.5.3.2. Landmark recognition

In this method, 5 landmarks in the study area (Centrum Galerie) were selected – at the same gazing angle. The landmarks are JD sportswear shop, Gelato Ice Cream shop, sitting space, Sparkasse ATM machine and Kiko Make-up Milano shop. Aside from the selected images termed as "correct images", 5 incorrect images which look similar to the correct ones were also selected and paired to their corresponding correct ones. This is shown in figure 5.

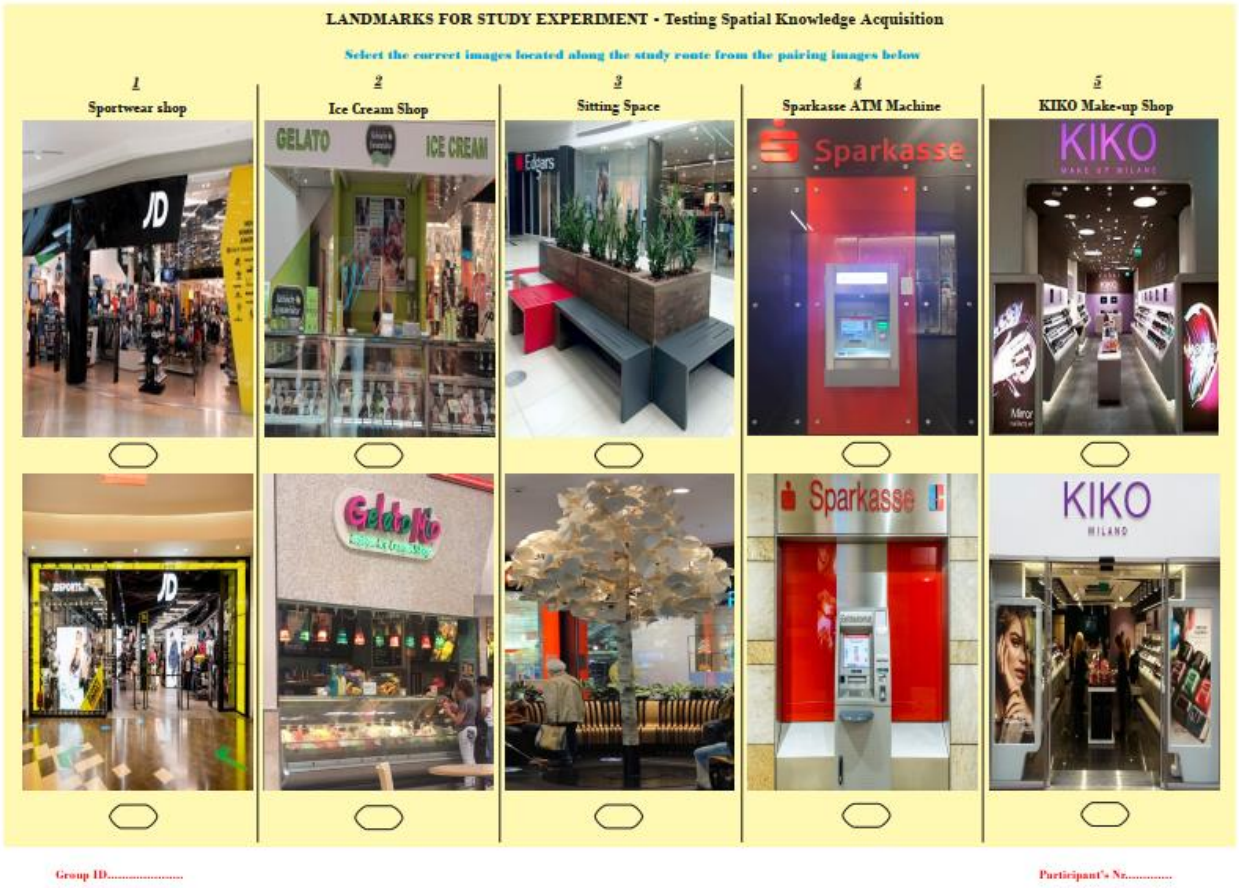


Figure 5: ***Pairing images***

Source: ***Julius Nyonyo, 2022***

The paired images are then split on a table for the participants to select the correct images that they deemed are from the study area. This exercise is performed based on groups (PM and MNS groups) and with participants from each group performing it one after the other.

Figure 6: ***landmark recognition exercise***

Source: ***Julius Nyonyo, 2022***

3.5.3.3. Estimation of landmark locations

The last method considered by the researcher to test the spatial knowledge of the participant is estimating the location of some selected landmarks from the study area on a map designed by the researcher. There are 5 landmarks selected from the study area and their locations are approximately marked on the map. The names of these landmarks are as well provided, but mixed up. Participants are to observe and match or write the name of the landmark to its corresponding marker. This is shown in figure 7.

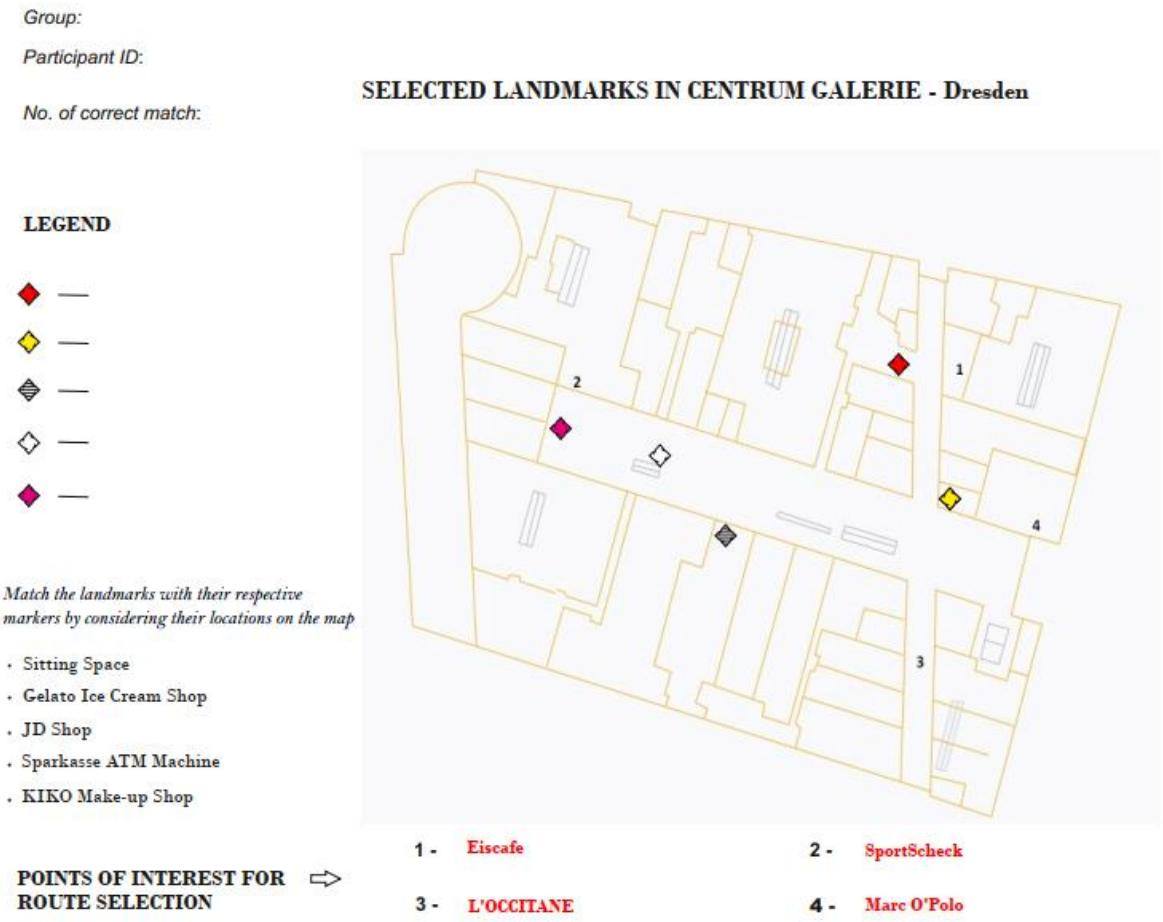


Figure 7: ***Template for landmark location matching***

Source: ***Julius Nyonyo, 2022***

In figure 8, the researcher correctly matched the names of the landmarks to their corresponding markers – that is indicating their correct locations. This map was prepared in order to help the researcher to identify landmarks which have been correctly matched or wrongly matched by the experiment participants. This map will also be useful in the process of analysis as well.

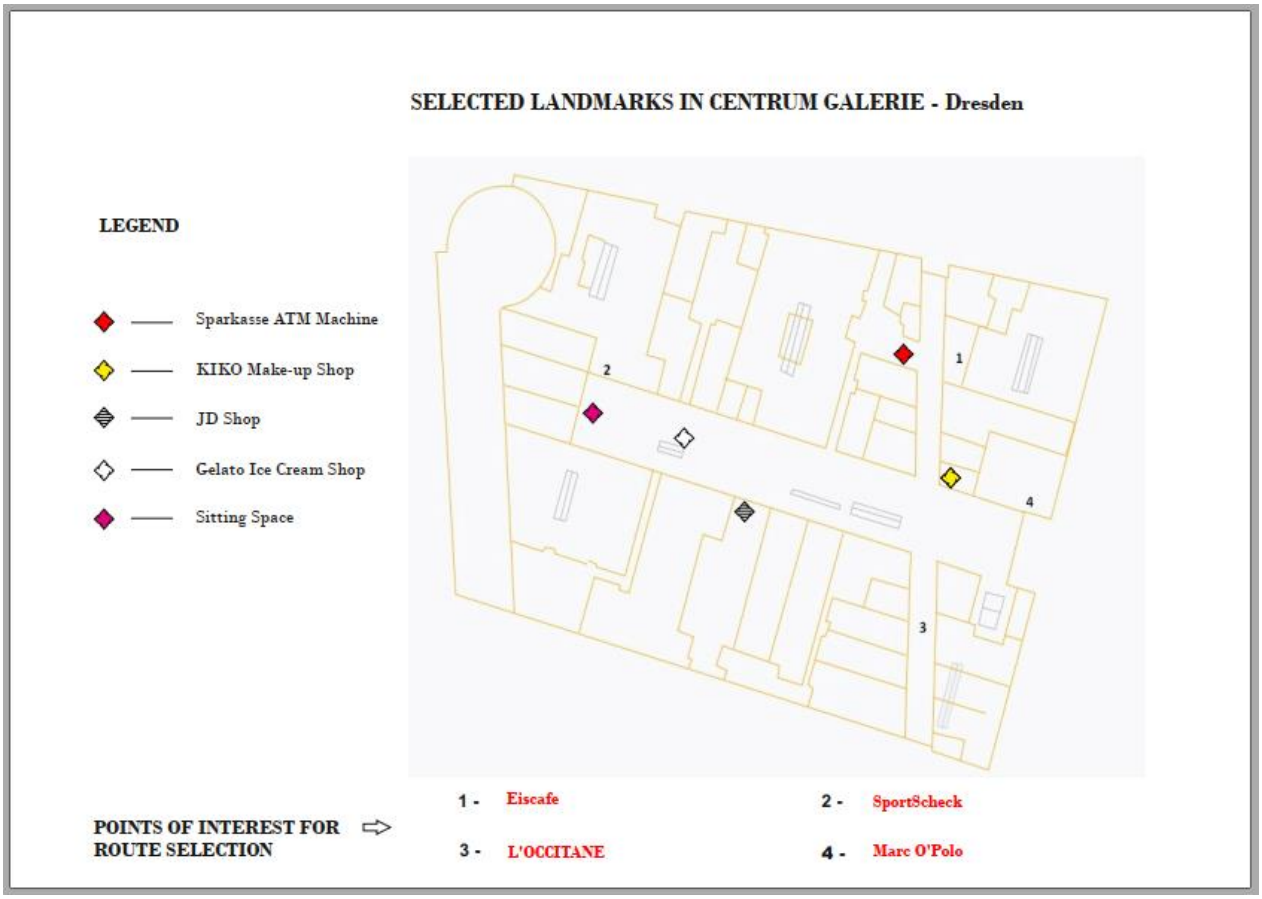


Figure 8: ***Correctly matched location of landmarks***

Source: ***Julius Nyonyo, 2022***

3.6. Survey

Inasmuch as the research was designed on study experiment, there was the need for the participant to share their views on the general procedure of the experiment, their intake on using and not using maps to navigate and how the maps assisted them to learn about the environment. In this regard, the researcher devised a questionnaire consisting of both open and closed-ended questions to administer immediately after the experiment.

3.7. Data Analysis

This part of the study shows how the data collected for the result will be analysed. It consists of the methods used in analysing data and explanation to the main test statistics that was employed.

3.8. Method

The researcher will apply the mixed method of data analysis. Alongside collecting quantitative data, the qualitative one was also collected and hence the need to fall on the mixed method in analysis of the data.

Chapter four

DATA PRESENTATION AND ANALYSIS

4.1. Introduction

The results of the study are contained in this chapter. The chapter is divided into two parts. First, there will be a presentation of data that were collected before, during and after the experiment. The main constituents of the first part are description of sample participants and presenting the results of the experiment. The second part will delve into a comprehensive analysis of collated data based on the objectives of the research.

4.2. Presentation of data

This section of the chapter presents the results of the data that were collected. The section is also sub-divided into two: *description of sample participants* which comprises the demographic characteristics of participants, knowledge about study area and experience in map usage. The other section, *results of experiment* also consists of navigation by paper map group, navigation by mobile navigation service group, pointing task by each group, pairing images and estimation of landmark locations.

4.2.1. Description of sample participants

4.2.1.1. Demographic characteristics of participants

In total, 20 people were recruited for the experiment from neighbouring cities of Dresden – Freiberg and Leipzig. 12 (6%) of the participants were from Freiberg and 8 (40%) from Leipzig. 12 (60%) of these participants were males and 8 (40%) of them were females. The highest age group of the participants was between 15 – 19 years. There were also 9 (45%) participants in this age group with 8 (40%) falling between 20 – 24 years and 3 (15%) between 25 – 29 years. With respect to the educational level and occupation, all participants are in a university pursuing either BSc, MSc, PhD or other university courses? *See table 1 below*.

Table 1: ***Demography of participants***

Age	15 – 19	9	45%
	20 – 24	8	40%
	25 – 29	3	15%
	30 - 34	-	-
Gender	Male	12	60%
	Female	8	40%
Education	Basic School	-	-
	High School	-	-
	University (BSc, MSc, PhD, etc.)	20	100%
City	Freiberg	12	60%
	Leipzig	8	40%
Occupation	Student	20	100%
	Others	-	-

Source: ***Pre-experiment survey by Julius Nyonyo, 2022***

4.2.1.2. Knowledge about study area

Participants were also examined based on their familiarity or visitation to the study area. The questions asked by the researcher in this category were whether the participants have been to Dresden before or Centrum Galerie. Per their responses, 9 (45%) participants have been to Dresden before but not Centrum Galerie. 11 (55%) of the participants have neither visited Dresden nor Centrum Galerie before.

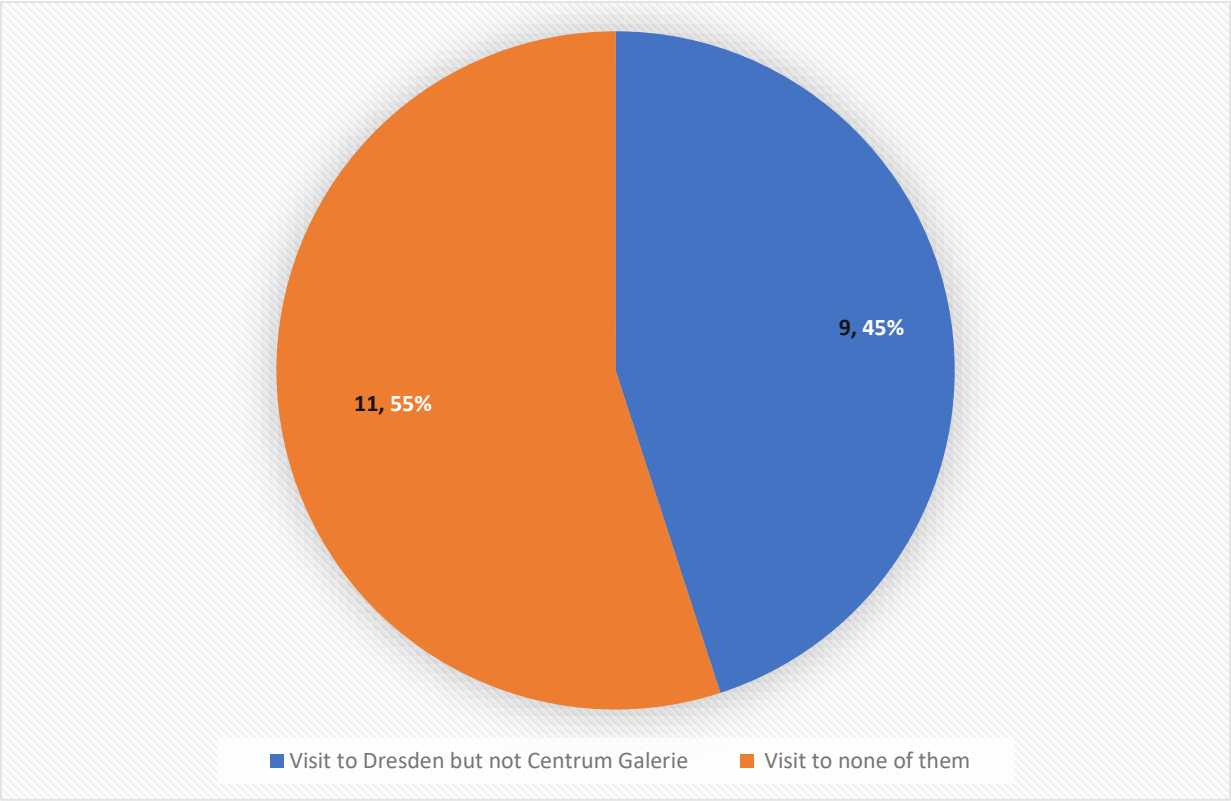


Figure 9: ***Visit to Dresden and Centrum Galerie***

Source: ***Pre-experiment survey by Julius Nyonyo, 2022***

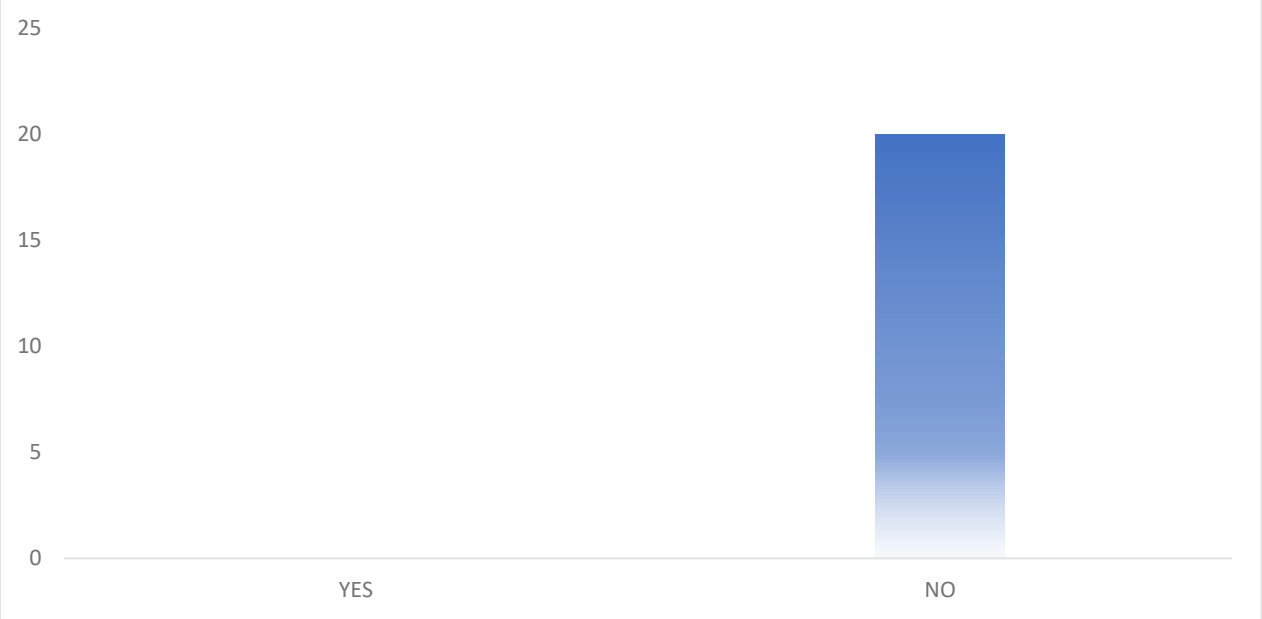


Figure 10: ***Visit to Centrum Galerie***

Source: ***Pre-experiment survey by Julius Nyonyo, 2022***

4.2.1.3. Experience in map usage

The researcher wanted to know the participants' experience in the use of maps. According to the data collected, 8 (40%) participants have exclusively used Mobile Navigation Service (MNS) whilst 12 (60%) participants said they have used both MNS and paper maps (PM) before. Among the participants, 1 (5%) person said he used MNS for indoor navigation, 17 (85%) people used it for outdoor navigation and 2 (10%) said they used it for both indoor and outdoor navigation. For paper maps, 11 (55%) of the participants said they used PM for only outdoor navigation.

Table 2: ***participants' experience in map usage***

Which	PM	-	-
	MNS	8	40%
	Both	12	60%
Where MNS	Indoor environment	1	5%
	Outdoor environment	17	85%
	Both environment	2	2%
Where PM	Indoor environment	-	-
	Outdoor environment	11	55%
	Both environment	-	-

Source: ***Pre-experiment survey by Julius Nyonyo, 2022***

4.2.2. Results of experiment

This section of the chapter presents the results of the experiment that was undertaken in the Centrum Galerie in Dresden, Germany. There are subdivisions under this section as well: navigation: paper map group, navigation: mobile navigation service group, pointing tasks, pairing images and estimation of landmark locations.

4.2.2.1. Navigation: paper map group

Figure 11 displays the result of the experiment on the use of paper map in navigating an indoor environment. Participants were asked to navigate the study zone with and without the map. After

the experiment, it was realised that all the participants used a total of 128 minutes with an average of 12.8 minutes to complete the navigation using the map while a total of 49 minutes averaging 4.9 minutes to complete the reverse navigation without using map. During navigation with a map, the average stop (*point at which a participant stops to decide the next direction to take*) was at least 5 times, but the average number of stops without the map was at least once. Refer to *appendix 3* for further insight.

From the result of the experiment, a grouped bar chart was drawn to depict the trend of the data. From fig.11, every participant from the paper map group used more minutes to navigate with map than without map.

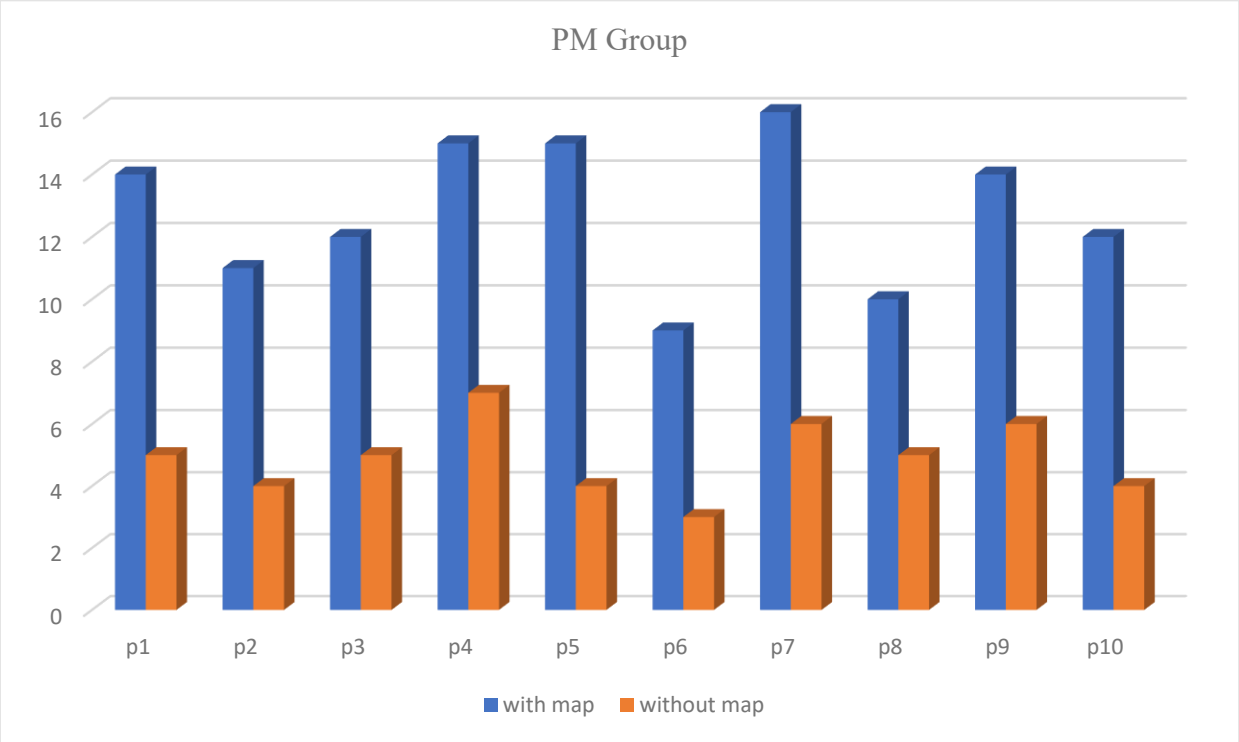


Figure 11: ***Result (in minutes) of navigation experiment for paper map group***

Source: ***field experiment by Julius Nyonyo, 2022***

4.2.2.2. Navigation: mobile navigation service group

The indoor navigation exercise was also conducted for another set of group who used mobile navigation service (Google Maps). The result of the exercise revealed that participants were able to navigate faster when using MNS than when they do not use it. Different from the paper map

group, a total of 44 minutes was used by the participants to finish the first set of the exercise – that is navigating with the help of MNS – averaging at least 4 minutes per participant. On the other hand, a sum of 130 minutes was used to complete the retreat experiment – that is without using MNS. This averages 13 minutes per participant. Total number of *stops* with map was 5 with an average of maximum 1 *stop*. The reverse navigation recorded 52 *stops* where MNS was not in use. This averages at least 5 *stops* per participant. See *appendix 4* for further details.

Figure 12 shows the distribution of the experiment for *with map* and *without map*. From the figure, it was realised that the participant form MNS group, unlike the PM group, used less minutes to navigate with map than without map. Further explanation to this will be covered in the data analysis section.

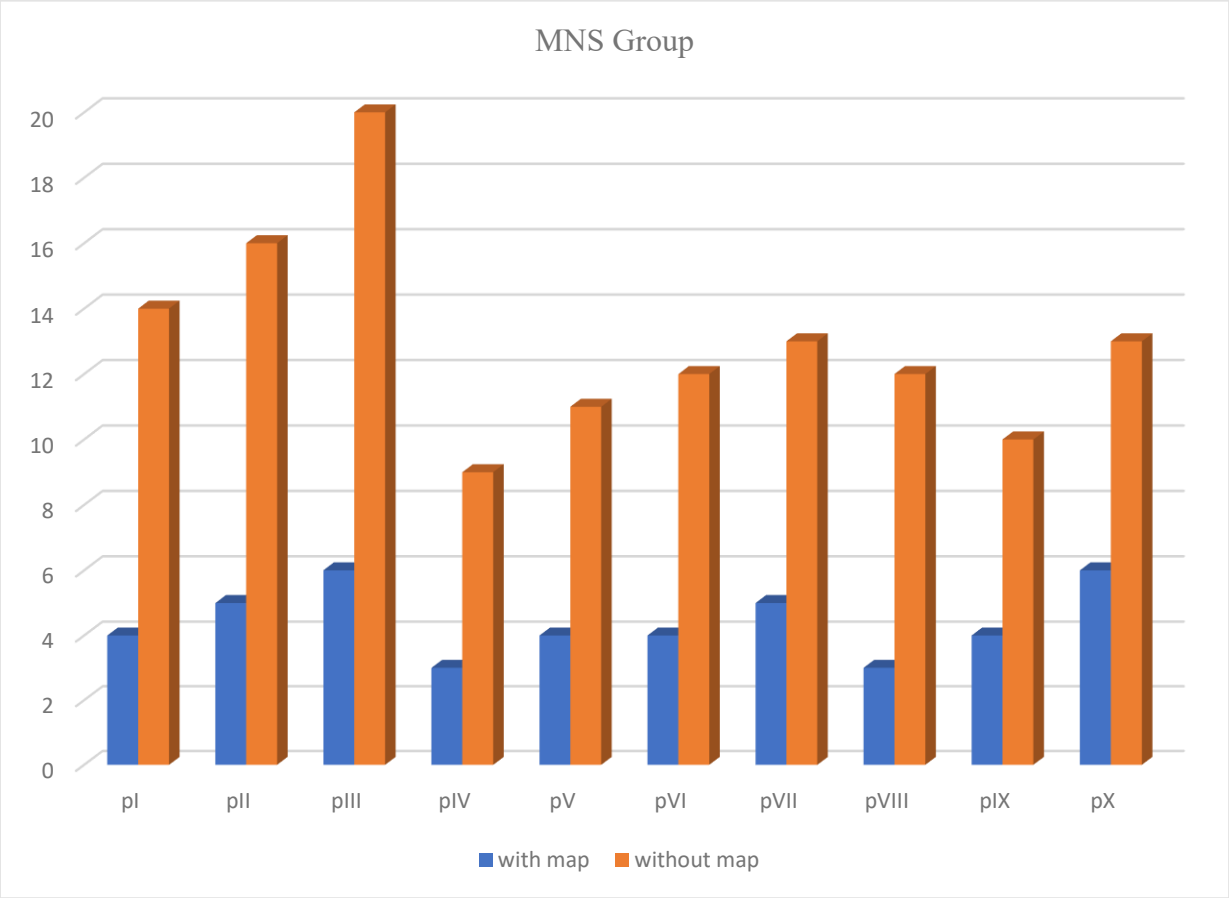


Figure 12: ***Result (in minutes) of navigation experiment for mobile navigation service group***

Source: ***field experiment by Julius Nyonyo, 2022***

4.2.2.3. Pointing task

There was a pointing task exercise to test memory recall and spatial direction of the participants. The two groups for the experiment performed the pointing task separately and this is reported in different sub-sessions. The result of the task is displayed in a tabular form for easy reading and understanding of readers.

4.2.2.3.1. Pointing task: PM group

Pointing task was performed among the PM group and the result is shown in table 3. The angle measured by the researcher prior to the exercise was 052°. After the experiment, it was realised that all the participants from the PM group had their angles close to that of the original one. The difference in angle ranges is $015° \leq X \geq 070°$. This means that the least deviation was 015° and the highest deviation was 070°.

Table 3: ***Result of pointing task for PM group***

PM Group

Participant ID	*Original angle*	*Participant angle*	*Angle difference*
P1	052°	104°	052°
P2	052°	080°	028°
P3	052°	122°	070°
P4	052°	109°	057°
P5	052°	067°	015°
P6	052°	091°	039°
P7	052°	089°	037°
P8	052°	096°	044°
P9	052°	072°	020°
P10	052°	065°	013°

Source: ***field experiment by Julius Nyonyo, 2022***

4.2.2.3.2. Pointing task: MNS group

Same as the PM group, the pointing task was also executed for the MNS group of participants. The outcome of the pointing task exercise here indicated great deviation from the original angle (that is 052°). The range of deviation here was 032° ≤ X ≥ 76°. The least deviation was at 032° and the highest deviation was at 76°. This is shown in table 4 below.

Table 4: ***Result of pointing task for MNS group***

MNS Group

Participant ID	*Original angle*	*Participant angle*	*Angle difference*
PI	052°	114°	062°
PII	052°	083°	031°
PIII	052°	128°	076°
PIV	052°	120°	068°
PV	052°	112°	060°
PVI	052°	084°	032°
PVII	052°	113°	061°
PVIII	052°	120°	068°
PIX	052°	127°	075°
PX	052°	116°	064°

Source: ***field experiment by Julius Nyonyo, 2022***

4.2.2.4. Landmark recognition

One of the tasks that was also undertaken by the researcher to test the spatial knowledge of participants was the issuance of pairing images of landmarks of the study location. These landmarks consist of 5 correct ones and 5 incorrect ones. Each group was given these images to select the correct ones (5 correct images). From table 5, it could be seen that from a possible 50 correct images (10 x 5) for MNS group, only 17 images were selected correctly with an average of

at most 2 correct images per participant. Also with a possible 50 total correct images (10 x 5) for the PM group, 44 images were correctly selected with an average of at least 4 images per participant.

Table 5: ***Result of landmark recognition task***

Group	***Number of participant***	***Correctly selected images***	***Approximated correctly selected images per participant***
MNS	10	17	≤ 2
PM	10	44	≥ 4

Source: ***field experiment by Julius Nyonyo, 2022***

4.2.2.5. Estimation of landmark locations

Participants were also tested on the location of selected landmarks in the study zone. Same as the "pairing images" exercise, participants were asked to match the names of the landmarks to their corresponding marker (see figure 13 for example result for participant 6 in PM group).

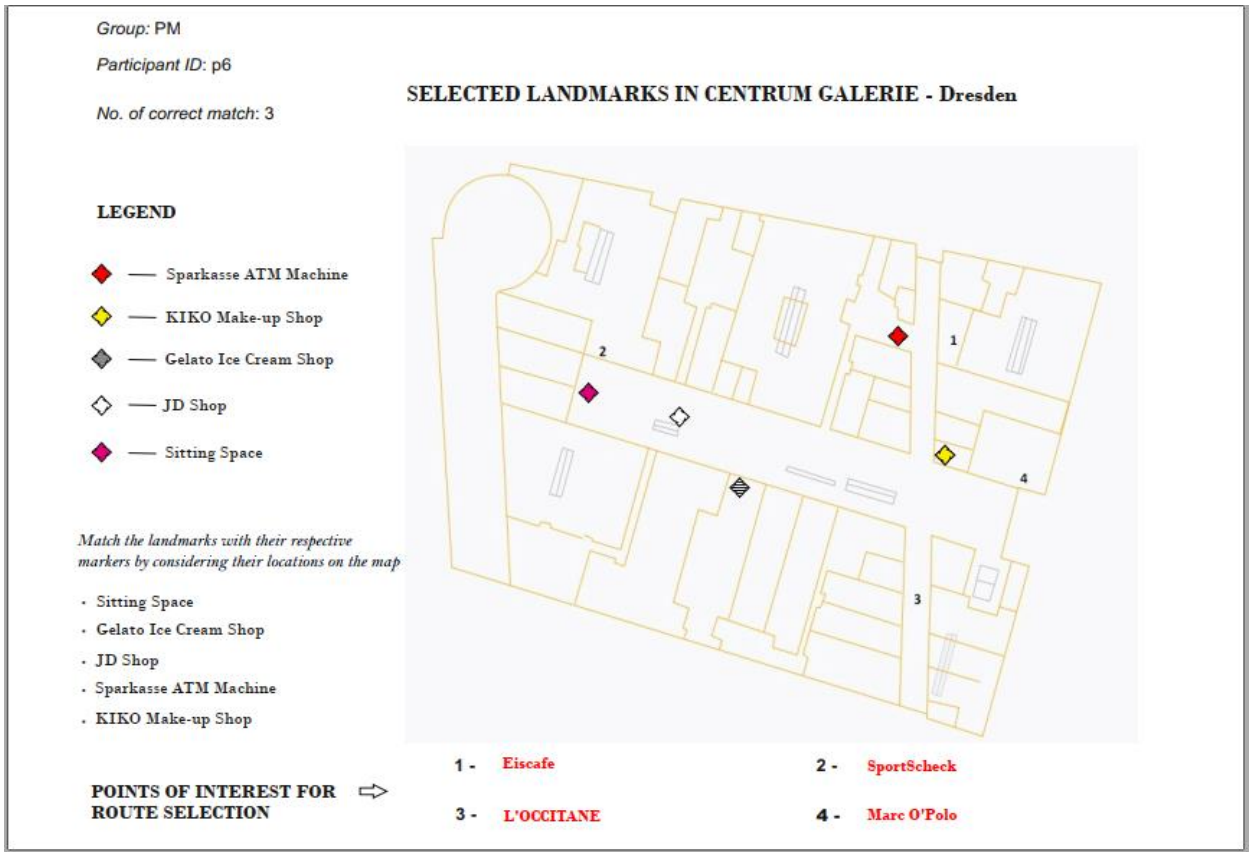


Figure 13: ***Example result*** *of* ***landmark location matching for participant 6 in PM group***

Source: ***by Julius Nyonyo, 2022***

From the result of this experiment, participants in the MNS group managed a total of 11 correctly matched landmarks with each in this group managed to match at least 1 landmark correctly. With the PM group, a total of 43 landmarks were correctly matched with an average of at least 4 landmarks matched correctly per every participant.

Table 6: ***Result of landmark location estimation by participants***

Group	***Number of participant***	***Correctly matched landmarks***	***correctly matched landmarks per participant***
MNS	10	11	≥ 1
PM	10	43	≥ 4

Source: ***field experiment by Julius Nyonyo, 2022***

4.3. Data analysis

4.3.1. The Mann Whitney U test

The most statistical test used in analysing the data is the Mann Whitney *U test.* This test statistic is good for comparing two independent variables and this proves as a good choice for testing the research hypotheses because the data collected are not normally distributed. Analysis will be done based on the results from the Mann Whitney *U* test.

4.3.2. Efficiency of indoor navigation: comparing PM and MNS

The efficiency in this aspect mainly refers to time. That is the amount of time a pedestrian uses in navigating a route. Most research work (Münzer et al., 2006, Ishikawa et al., 2008, Gardony et al., 2013, Taylor et al., 2008, Parush et al., 2007) on paper map and mobile navigation services have confirmed how fast people can navigate with mobile navigation service (e.g. Google Maps) rather than the paper maps which often delay or retard the navigation since pedestrians have to interact more with paper maps. All of these studies on the comparison between PM and MNS in terms of time efficiency or fastness in navigation, were conducted in the outdoor environment.

This research work was conducted to explore the same time efficiency between PM and MNS in the indoor environment. The results of the experiment conducted in this aspect of the thesis were presented in the previous sub-headings. As seen in figures 3 and 4, it was realised that pedestrians who used paper maps to navigate, used more time (128 minutes in total) than pedestrians who used the mobile navigation service (44 minutes in total). This could easily confirm that the same as in the outdoor environment, in the indoor environment too, pedestrians who navigate with mobile navigation service are time efficient as compared to people who use paper maps. However, the result of the study also indicated that there could be an instance where people who used paper maps for their first time navigation, can be more time efficient than people who used mobile navigation service during their first time navigation. This assertion was evidenced when both PM and MNS groups were asked during the experiment to navigate back to the starting point without using maps. At this instance, the MNS group could not beat the PM group in terms of time efficiency. The reason for this confirms the assertion in the findings of Münzer et al (2006) that people who use paper maps to navigate have well acquainted themselves with the environment in that they can navigate easily and faster unlike pedestrians who use mobile navigation service which normally suggests the direction for the users instead of the users finding their own routes in the environment.

The result from the research experiment indicated this assertion (see figures 11 & 4) where MNS group without map use a total of 130 minutes to navigate the selected route while PM group used only 49 minutes.

4.3.2.1. Efficiency with map: comparing PM and MNS

Comparing PM group and MNS group in terms of efficiency of navigation with map, participant in the MNS group finished their navigation in very short time as compared with the PM group. This result shows that navigators who use mobile navigation services to find their locations, turn to find it faster than those who use paper maps as this is depicted in figure 14 where MNS participants used less time than PM participants.

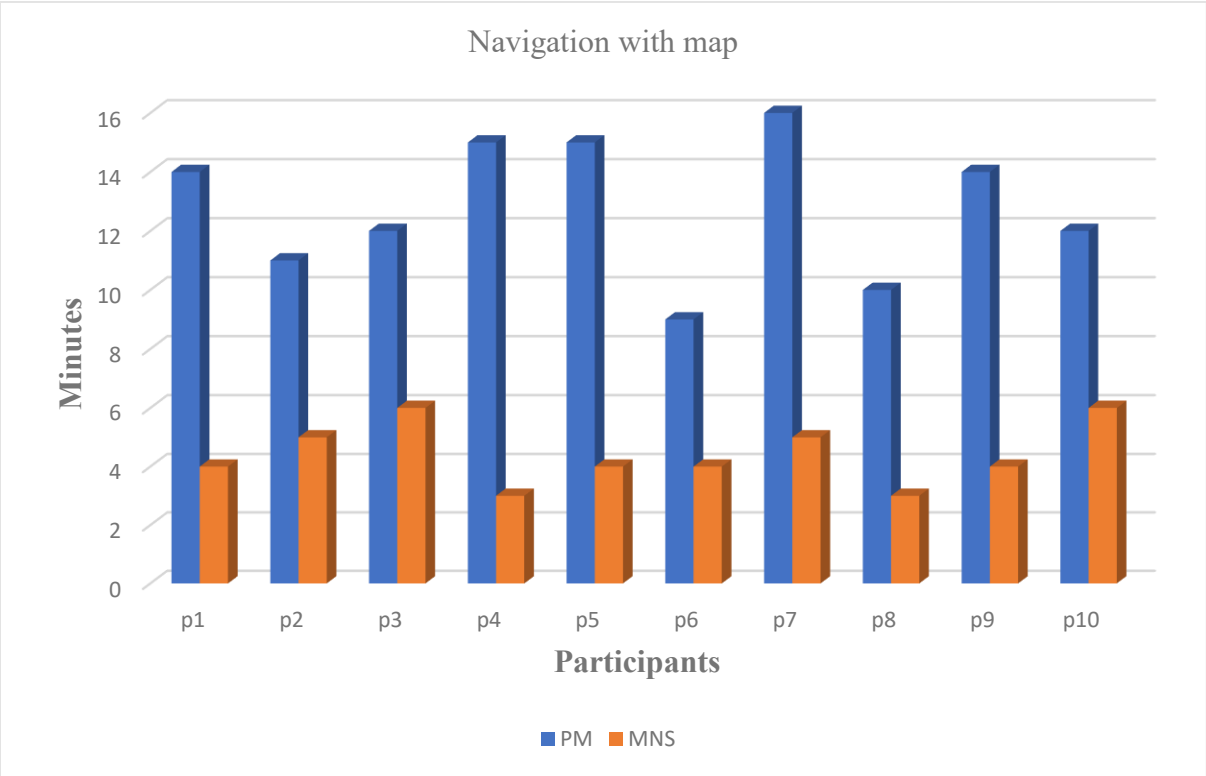


Figure 14: ***Time used for navigating with map by each group member***

Source: ***field experiment by Julius Nyonyo, 2022***

4.3.2.1a. Mann Whitney U test

After performing the Mann Whitney U test, U =20 .000, W = 55.000, Z = -3.803 and *P-value* = .061. Since p-value is greater than 0.05, we fail to reject the null hypothesis (Brügger et al., 2019) that, "*navigating with mobile navigation services is more time efficient than paper maps*", in the sense that the result of the test experiment does not show significant difference to reject the null hypothesis. In the data presentation session, the-navigation-*with-maps* results between the 2 groups (PM and MNS) (*see figures 11 and 12*) indicated that the PM group used more time (128 minutes) for navigating the same route than the MNS group who used only 44 minutes. Again, we can also infer from figure 14 that every participant in the MNS group used less time than the participants in the PM group. This shows a tendency of people with MNS were faster and time efficient than people with PM. This could be as a result of participants in MNS group do not have to spend time in deciding their own route unlike the PM group who spend most of the time with their maps to decide where to pass. With MNS, the route is predefined by technology. However, the insignificance in data could be a

result of the sample size. The study considered only 10 participants in each of the two groups. The result might have changed if sample size was more.

4.3.2.2. Efficiency without map: comparing PM and MNS

The reverse experiment was also conducted for the two groups. At this time, participants navigate to the starting point of the route without using maps. Per the result of the experiment, PM group used less time to finish the navigation exercise than those in the MNS group. The result of this is shown in the grouped bar chart in figure 15.

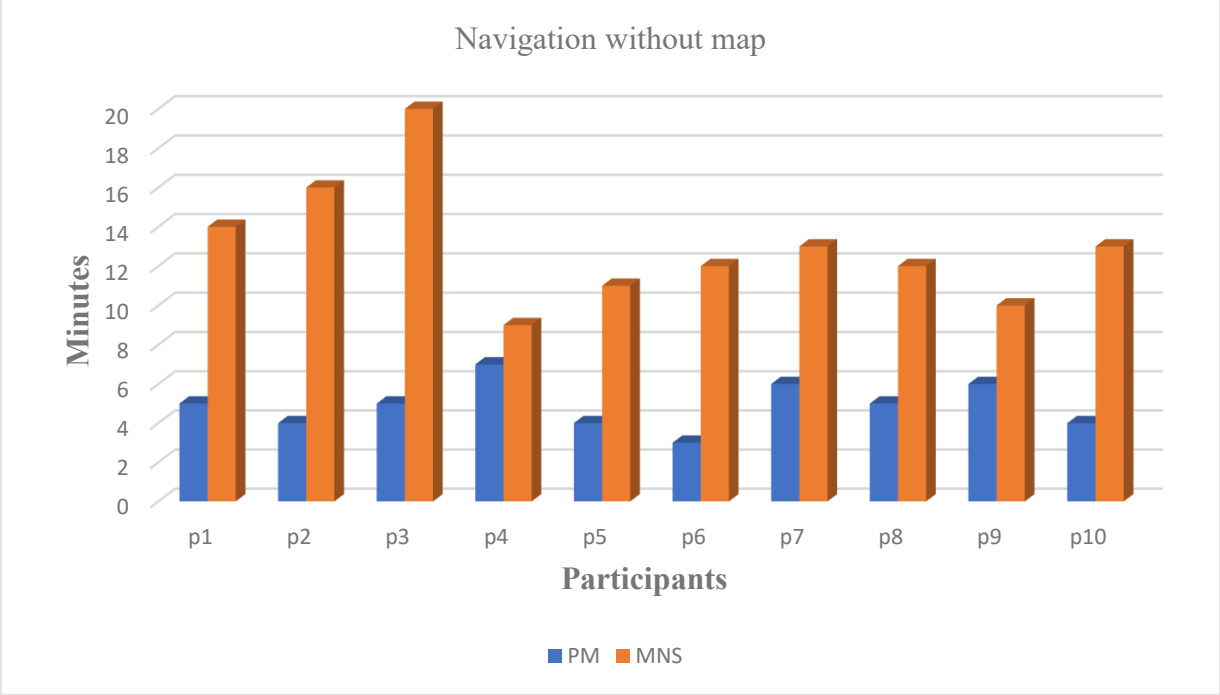


figure15: ***Time used for navigating without map by each group member***

Source: ***field experiment by Julius Nyonyo, 2022***

4.3.2.2a. Mann Whitney U test

The test statistic also showed a Mann Whitney U test as $U = 35.000$, $U = 55.000$, $Z = -3.795$ and *P-value* = .130. In this analysis, we can interpret that since p-value is greater than 0.05, then, there is no significant difference or evidence to reject the null hypothesis (that *pedestrians who use paper map to navigate once can navigate faster than those who used mobile navigation services)*. The result indicates that the MNS group in this aspect used more time to navigate than the PM group (in figure 15). This shows that while both groups used their respective maps to navigate in the first round, PM group had ample time to interact with the environment and thereby, they were more

acquainted with the environment and can navigate faster without using map than MNS group who solely depended on route direction and hence they were unable to navigate fast or efficiently without using maps. Therefore, in this scenario, there is tendency that pedestrians who used paper maps before to navigate a specific route can navigate the same route faster in terms of time efficiency without using map than someone who used mobile navigation services before to navigate the same route and also now navigating without a map.

4.3.3. Acquisition of spatial knowledge: comparing PM and MNS

To test the spatial knowledge acquisition of pedestrians, three methods were used. These are the *pointing task,* the use of *pairing images* and *landmarks location estimation.* The result of these methods were reported in the previous sections. The following sections presents the analysis of these methods using the *Mann Whitney U* test statistics.

4.3.3.1. Pointing task

The pointing task was one of the methods used to explore the spatial knowledge acquisition of pedestrians. This method compared the use of paper map and mobile navigation services. The data from this exercise revealed that people who use paper map for navigation got most of their angles close to the original angle – that is, the angles the paper map group drew were almost equal to the one (052°) that was determined by the researcher. This shows an evidence that people who used paper map for the navigation exercise had a good insight of the environment and as such, they were able to locate the starting point by drawing a line from the center of the a circle towards the direction of the starting point. On the other hand, pedestrians who used mobile navigation service for the navigation exercise could not locate the starting point unlike that of the PM group. In this aspect, we could comment that people who normally rely on mobile navigation services for navigation have less insight of their environment and hence have less spatial knowledge of the environment. See tables 3 and 4 for the result of the exercise.

In figure 16, comparison of difference in angle (x – 052°) between the use of paper map and mobile navigation service was presented in a grouped bar chart and from the diagram, the MNS group deviated more than the PM group from the original angle of the pointing task of 052°. This indicates the possibility of MNS group acquiring less spatial knowledge of the environment than PM group.

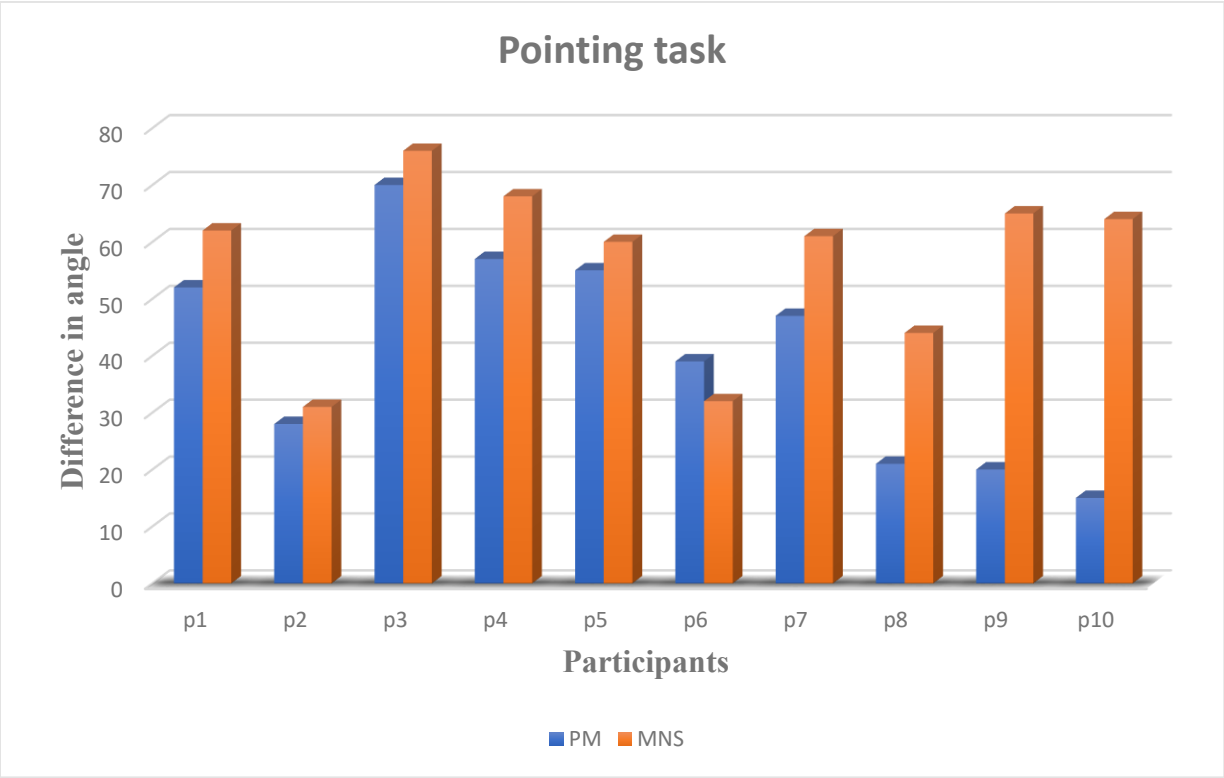


Figure 16: ***Angle differences from pointing task by each group member***

Source: ***field experiment by Julius Nyonyo, 2022***

4.3.3.1a. Mann Whitney U test

After running the Mann Whitney *U* test, $U = 25.000$, $U = 85.000$, $Z = -2.541$ and *P-value* = .140

From the test statistics, p-value is greater than 0.05 and therefore, we fail to reject the null hypothesis that *paper map enables better spatial knowledge acquisition than mobile navigation services.* In this sense, there was no significant evidence to reject the claim. From figure 16, the smaller the number, the closer the participant's angle to the original angle (052°). From the figure, participants in the PM group had their angles close to the original one than the participants in the MNS group. Taking inference from the chart, there is an evidence that PM group acquired more spatial knowledge than MNS group during the experiment.

4.3.3.2. Landmark recognition

Another method devised by the researcher to test the spatial knowledge acquisition of pedestrians was the use of pairing images comprising 5 correct images from the study area and 5 incorrect images, but almost similar which are not found in the study area. From the result of this landmark recognition exercise, participants in the paper map group selected more correct images in total than

those in the mobile navigation service group. This indication also shows a sign that people who use paper maps for navigation end up acquiring more spatial knowledge than those who use mobile navigation services (see figure 17).

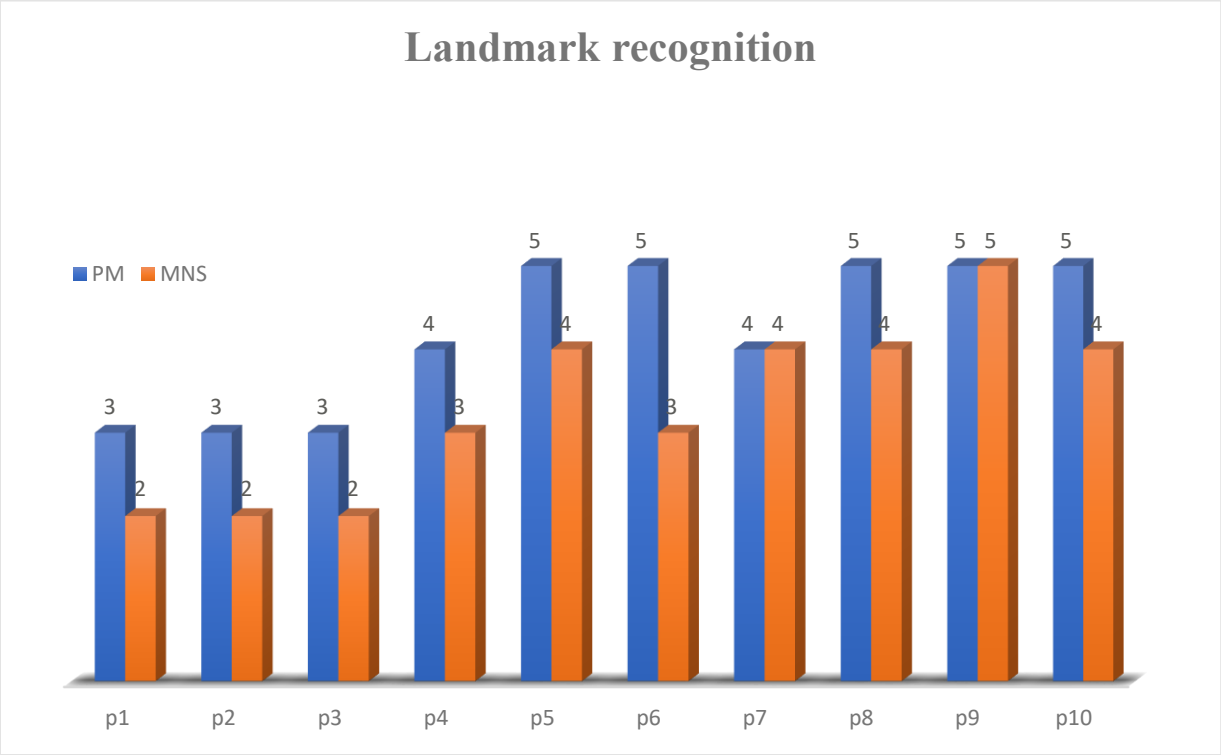


Figure 17: ***Number of correctly selected landmarks by each group member***

Source: ***field experiment by Julius Nyonyo, 2022***

4.3.3.2a. Mann Whitney U test

The *Mann Whitney U* test was performed on the results from the landmark recognition exercise to verify research *hypothesis 3*. After conducting the test, the value of $U = 500$, $W = 55.5$, $Z = -3.816$ and *P-value* = .051. Per the test statistics, there is no significant difference to reject the null hypothesis since p-value is greater than 0.05. In this sense, there is evidence that navigating with paper maps creates more avenue for acquiring spatial knowledge than mobile navigation services since PM group were able to recognise more correct landmarks in the study area than MNS group.

4.3.3.3. Location Estimation of Landmarks

The last method used by the researcher to test the spatial knowledge acquisition of participants was estimating the location of some selected landmarks in the study zone. The position of 5 landmarks were selected for the experiment. Of the 5 landmarks, results showed that participants who used paper map were able to match most landmarks to their corresponding markers correctly, unlike the mobile navigation service group. The outcome of this exercise gives a clear indication that using paper map to navigate makes pedestrians learn more about the environment and thereby enable them to acquire more spatial knowledge than using mobile navigation services. This result is shown in the grouped bar chart in *figure 18.*

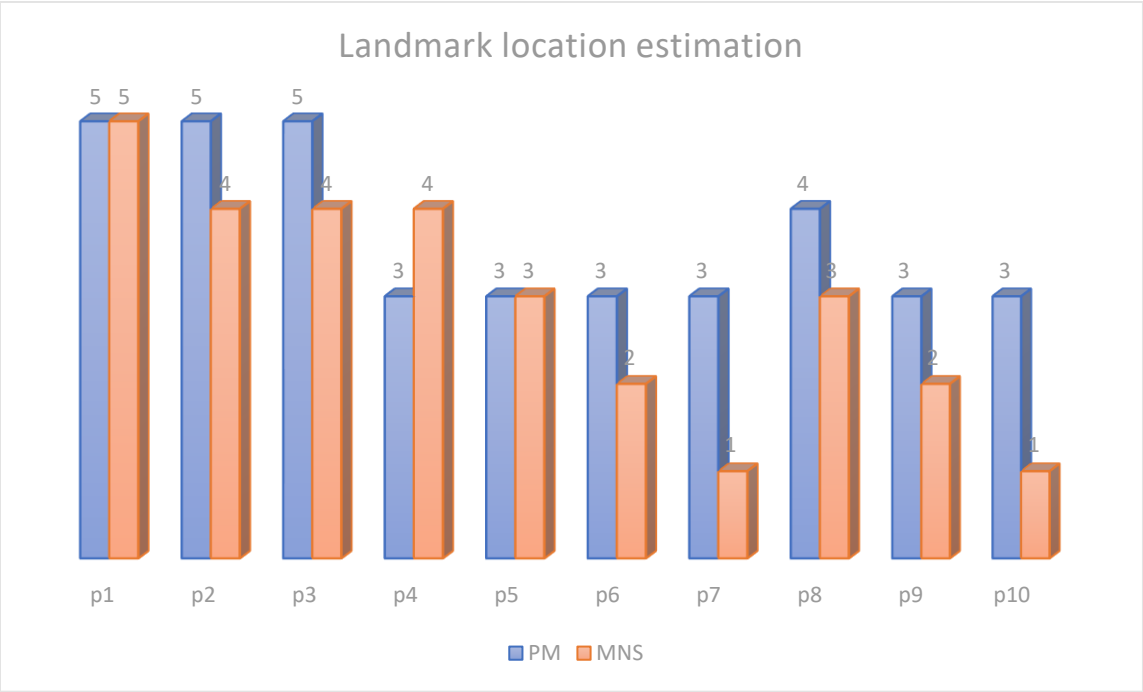


Figure 18: ***Number of correct estimate of landmarks by each group member***

Source: ***field experiment by Julius Nyonyo, 2022***

4.3.3.3a. Mann Whitney U test

To test whether people who use paper map for navigation learn more about the environment and acquire more spatial knowledge than those who use mobile navigation Service, the Mann Whitney *U* test was utilized. The result of the test shows that: $U = 20,\ W = 75,\ P\text{-}value = .079$. From the test statistics, there is no significant difference or enough evidence to reject the null hypothesis since the P-value obtained from the test is greater than 0.05. This means that we maintain the null hypothesis which states that paper map enables better spatial knowledge acquisition than mobile navigation services. In other words, when we look at the number of correctly estimated locations for PM group (43) and that of MNS group (11) (*see table 6)* we can conclude that pedestrians acquire spatial knowledge when using paper maps to navigate than mobile navigations services.

4.4. Post experiment survey

This section of the thesis was executed to solicit the general perception of the research experiment and also to pull knowledge from participants on how they see paper maps and mobile navigation services impacting on their navigation skills and acquiring of spatial knowledge.

4.4.1. General performance of the research experiment procedure

Table 7: ***Response on the performance of the research experiment procedure***

Scale	Frequency	Percent	Cumulative
5	1	5.0	5.0
6	1	5.0	10.0
7	5	25.0	35.0
8	10	50.0	85.0
9	3	15.0	100.0
Total	20	100.0	

Source: ***field experiment by Julius Nyonyo, 2022***

Participants were asked to rank the general procedure of the experiment on the scale of 1 – 10. From the result, 50% of the survey participants ranked the general experiment procedure at 8. None of the participants ranked the experiment below 5. This shows that the experiment was well organized and well received by the participants. The result of this is also displayed in *figure 14* chart for better visuals.

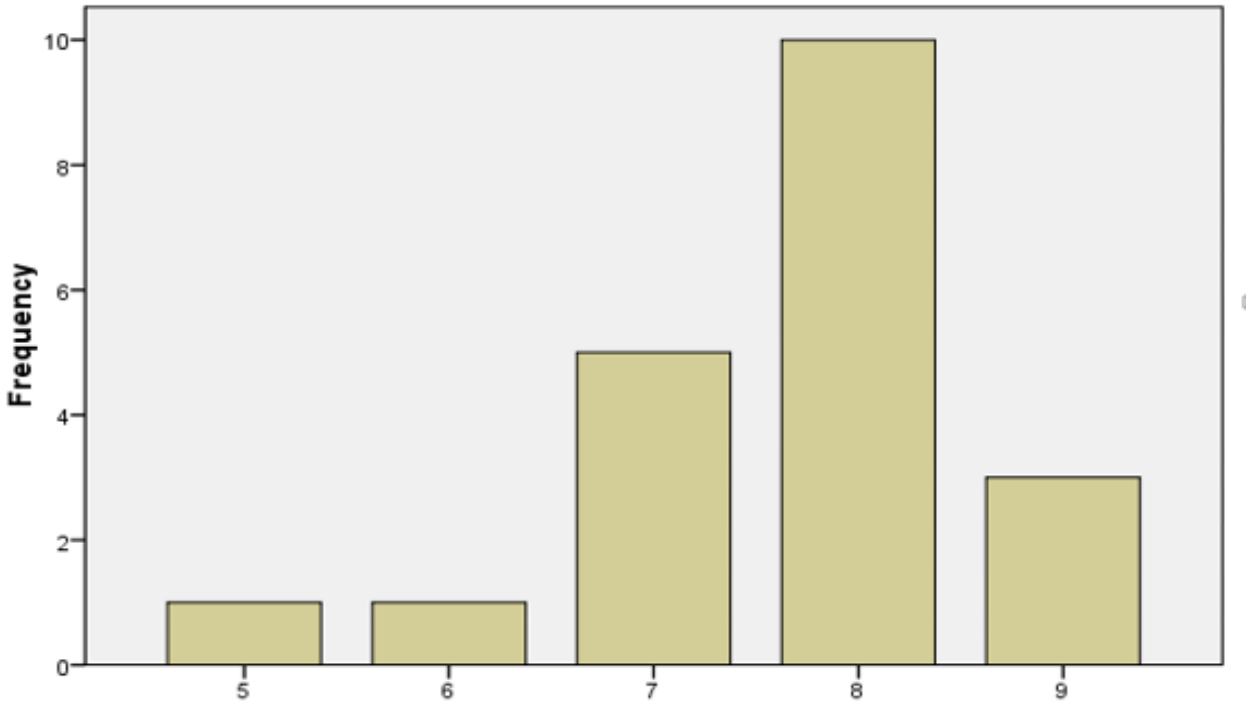


Figure 19: ***Histogram showing result of experiment procedure***

Source: ***field experiment by Julius Nyonyo, 2022***

4.4.2. The ease or difficulty of navigating to the starting point

There was a section in the survey questionnaire about how easy or difficult it was when participants were asked to navigate to the starting point without using maps. The responses from the participants are demonstrated in figure 19. From all indications, the PM group found moving to the point without a map as easy. The table shows that all the 10 participants reported that it was easy or very easy to move to the starting point without using maps. On the other hand, 9 participants from the MNS group either found this exercise as difficult or very difficult with only 1 participant from this group saying he or she found moving back to the starting point without a map easy.

From this survey, it makes it clear why the PM group used less time (49 minutes) in navigating back to the starting point than the MNS group (130 minutes) during the navigation experiment (see figures 3 and 4).

Table 8: ***Response on navigating back to the starting point***

GROUP			*Frequency*	*Percent*	*Valid Percent*	*Cumulative Percent*
PM	**Valid**	**Easy**	**2**	**20.0**	**20.0**	**20.0**
		Very Easy	**8**	**80.0**	**80.0**	**100.0**
		Total	**10**	**100.0**	**100.0**	
MNS	**Valid**	**Very difficult**	**8**	**80.0**	**80.0**	**80.0**
		Difficult	**1**	**10.0**	**10.0**	**90.0**
		Easy	**1**	**10.0**	**10.0**	**100.0**
		Total	**10**	**100.0**	**100.0**	

Source: ***field survey by Julius Nyonyo, 2022***

4.4.3 Identification and memorization of landmarks by the help of maps

Survey participants were asked if the different maps they used helped them in learning more about the environment in terms of identifying and memorizing landmarks. From the survey, all the participants in the PM group reported that the paper map has helped them to learn about the environment and even locate the positions of landmarks in the study area. On the other hand, MNS group said that the mobile navigation service neither helps them to learn more about the environment nor memorise landmarks and their locations. From their responses, we can also confirm the assertion that paper maps are good tools to enable people to learn more things about their environments and also help them in memorizing spatial features.

Table 9: ***Response on maps and their assistance in learning the environment***

GROUP			***Frequency***	***Percent***	***Valid Percent***	***Cumulative Percent***
PM	Valid	Yes	10	100.0	100.0	100.0
MNS	Valid	Neutral	1	10.0	10.0	10.0
		No	9	90.0	90.0	100.0
		Total	10	100.0	100.0	

Source: ***field survey by Julius Nyonyo, 2022***

Chapter Five

SUMMARY, DISCUSSION & CONCLUSION

5.1. Introduction

This chapter presents the general summary of the research. It presents the summary on the research background, objectives of the study, methodology, literature and research findings. The chapter also gives precise conclusions to the research findings.

5.2. Summary

5.2.1. Research Background

Navigation was of immense importance to the research. It was described in this study as the art and science of finding locations. From literature, in present times, navigation is mostly done by the help of navigation aids, especially with the help of mobile navigation services (e.g. Google Maps, compasses, etc.). These navigation aids are of great importance in the field of navigation and efficient use of time. However, they are seen as equipment that reduce humans' own efforts in finding locations on their own and they also do not help pedestrians to become familiar with their environments. Previous researchers concluded that acquiring spatial knowledge is crucial in that if navigation systems fail, navigators can rely their spatially acquire knowledge to their ways out in the environment.

Several studies have tested spatial knowledge acquisition of pedestrians in the outdoor environment using both mobile navigation services and paper maps and comparing these maps to know which of them impacts more on the spatial knowledge acquisition of pedestrians. The least of this study was done in the outdoor environment and therefore, the main reason for this study is to test the spatial knowledge of pedestrians in the indoor environment comparing both paper maps and mobile navigation services.

5.2.2. Research Objectives

The main aim of the researcher is to test spatial knowledge acquisition of pedestrians by comparing the effects of paper maps and mobile navigation services on acquiring these spatial knowledge. Aside the main objective of the researcher, there was a secondary objective. This secondary objective was to explore how efficient is navigation with paper maps and mobile navigation services.

5.2.3. Materials and methods

Several materials were used for this research. The researcher used paper maps, Mobile navigation service (Google Maps), camera for taking photographs, Survey questionnaire, SPSS Software, Mathematical Sets and a digital publishing software (Scribus 1.5.8).

The research solely relied on the primary source of data since it was a first-hand data collected by the researcher. The data was collected both quantitatively and qualitatively by the use of questionnaire and study experiment. The analysis of these data was done mainly by the use of the Mann Whitney U test statistic**.**

5.2.4. Literature

The study found a couple of literature which investigated the effects between paper maps and mobile navigation services on the spatial knowledge acquisition of pedestrians. One school of thought asserted that there is a higher impact of learning the environment with paper maps than the mobile navigation services. They asserted that unlike MNS which detects movement of pedestrians, PM only gives a clue and the pedestrian himself has to select or determine the route he should follow. To them, when this happens, pedestrians have the chance to learn more about the environment since they always have to determine their own route to find their locations.

Another school of thought has was identified from literature was also in line with navigation efficient with paper maps and mobile navigation exercise. Per findings in this regard, researchers have found that using mobile navigation services to navigate is more efficient than using paper maps. Their assertions were based on time efficiency. They found that since, with MNS, pedestrians do not have to rely on the mental judgement to find their ways out but to follow a

predefined route by MNS, they move faster and find their locations quicker than those who use paper maps.

5.3. Discussion

The objectives of this study were to explore the efficiency of navigation using paper map and mobile navigation services, and also exploring the effects of paper maps and mobile navigation services on spatial knowledge acquisition. From the research findings, it was realised that navigation is with mobile navigation service showed tendency of making navigators move or locate their destinations faster than navigation with paper maps. Even though the test statistics showed a no significant difference in efficiency, there were still instances where participants in the mobile navigation services group recorded minimal time of navigation than participants in the paper map group. The test statistics also revealed insignificant difference in the retreat navigation experiment where navigators had to navigate without their maps. However, there was difference in time between the MNS group and the PM group. Retreat navigation experiment result showed that participants in the paper map group were able to finish the route faster than those who used the mobile navigation service. The insignificant result in the test statistics in this aspect could well be because of the sample size and the distance of the study route. The study only considered 10 participant apiece the two groups and the route for the navigation experiment was relatively short. These factors could be the cause of the insignificance in the test results. Studies (McMahon et al., 2015; Umek, 2017: Kyoko & Veronique, 2013) in the outdoor environment proved how fast pedestrians can move faster with mobile navigation services than paper maps and how fast people who used paper maps before can navigate quicker without maps than people who used mobile navigation services before. Here, in the indoor experiment, the study results showed the tendency of confirming the findings in the outdoor environment.

The studies also conducted test to explore the effects of paper maps and mobile navigation services on spatial knowledge acquisition of pedestrians. Pointing task, landmark recognition and the estimation of landmark locations were the methods employed for this test. The result from this exercise and the test statistics revealed no significant differences between the two groups. However, in all the three method to test spatial knowledge, it was realised that paper map groups showed the tendency of acquiring more spatial knowledge than those in the mobile navigation service group. In the pointing task exercise, participants with paper maps were able to draw their

lines to the starting point of the study route a bit accurate than those who used mobile navigation service. Again in the landmark identification exercise, paper map group were able to identify more correct landmarks in the study area than those in the mobile navigation services group. Also with the landmark location estimation, paper map group picked or matched more correct locations of landmarks in the study area than that of the MNS group. All these indications showed that paper map helps in acquiring more spatial knowledge than that of mobile navigation services. The result nearly, but support the assertion of Ishikawa et al (2008) that paper maps are the best for learning the environment and acquiring and improving one's spatial knowledge than mobile navigation services.

In general, the perception of the researcher is that mobile navigation services in the indoor environment are the possible tools for easy and fast navigation. In other scenario too, paper maps are possible tools for acquiring more spatial knowledge than mobile navigation services.

5.4. Conclusion

The research on the effects of mobile navigation services and paper maps on spatial knowledge acquisition has been done by a couple of researchers. Most of these research were done in the outdoor environment. Their findings were that between paper maps and mobile navigation services, paper maps are the best maps when it comes to learning the environment and acquiring better spatial knowledge. Their research and findings in this domain were additions to knowledge for posterity. However, these researchers fell short of considering the indoor environment.

With the gap in knowledge, this study solely considered the indoor environment in exploring how paper maps and mobile navigation services could affect spatial knowledge acquisition. Having in mind the objectives of this study, these are the following findings: 1) there is a possibility that navigation with mobile navigation services is faster (time wise) than paper maps, 2) There is a tendency that people who use paper maps for navigation before can navigate same environment faster than those who used mobile navigation services before, and 3) there is a tendency that paper maps are the best for learning the environment and acquiring more spatial knowledge than mobile navigation service.

Taking the findings of this research into consideration, the study cannot fully conclude that mobile navigation services are faster for navigation than paper maps and also that paper maps are the best

tool for acquiring more spatial knowledge than mobile navigation services. This is because the test results did not show significant difference between the two navigation aids – the reason for this could be the small sample size for the study experiment or the distance of the study route selected for the experiment.

.

REFERENCES

Mihai, B., Șandric, I., Săvulescu, I., & Chițu, Z. (2009). Cartography in Central and Eastern Europe. *Cartography in Central and Eastern Europe*, *1992*, 417–429. https://doi.org/10.1007/978-3-642-03294-3

Montello, D. R. (2005). Navigation. In P. Shah & A. Miyake (Eds.), The Cambridge handbook of visuospatial thinking. (pp. 257–294). Cambridge: Cambridge University Press. https://doi.org/10.1017/CBO9780511610448.

Parush, A., Ahuvia, S., & Erev, I. (2007). Degradation in spatial knowledge acquisition when using automatic navigation systems. In: Winter S., Duckham M., Kulik L., Kuipers B. (eds) Spatial Information Theory, COSIT 2007. Lecture Notes in Computer Science, vol 4736. Springer, Berlin, Heidelberg.

Kyoko K., & Véronique D. B. (2013). Spatial navigational strategies correlate with gray matter in the hippocampus of healthy older adults tested in a virtual maze. Frontiers in Aging Neuroscience 5, FEB (2013), 1–8. https: //doi.org/10.3389/fnagi.2013.00001

Eleanor A. M., David G. G., Ingrid S. J., Catriona D. G., John A., Richard S.J. F., & Christopher D. F. (2000). Navigationrelated structural change in the hippocampi of taxi drivers. *PNAS USA* 97, 8 (2000), 4398–4403. https://doi.org/10.1073/pnas.070039597

Parush, A., Ahuvia, S., & Erev, I. (2007). Degradation in spatial knowledge acquisition when using automatic navigation systems. In: Winter S., Duckham M., Kulik L., Kuipers B. (eds) Spatial Information Theory, COSIT 2007. Lecture Notes in Computer Science, vol 4736. Springer, Berlin, Heidelberg.

Taylor, H. A., Brunyé, T. T., & Taylor, S. (2008). Wayfinding and navigation: Mental representation and implications for navigational system design. Reviews of Human Factors and Ergonomics, 4, 1–40. https://doi.org/10.1518/ 155723408X342835

Gardony, A. L., Brunyé, T. T., Mahoney, C. R., & Taylor, H. A. (2013). How navigational aids impair spatial memory: Evidence for divided attention. Spatial Cognition and Computation, 13(4), 319–350. https://doi.org/10.1080/ 13875868.2013.792821.

Ishikawa, T., Fujiwara, H., Imai, O., & Okabe, A. (2008). Wayfinding with a GPS based mobile navigation system: A comparison with maps and direct experience. Journal of Environmental Psychology, 28(1), 74–82. https://doi.org/ 10.1016/j.jenvp.2007.09.002.

Huang H., Schmidt M., & Gartner G. (2012). Spatial Knowledge Acquisition with Mobile Maps, Augmented Reality and Voice in the Context of GPS-based Pedestrian Navigation: Results from a Field Test. *Cartography and Geographic Information Science* 39, 2 (2012), 107–116. https://doi.org/10.1559/ 15230406392107

Rehrl K., Häusler E., Leitinger S., & Bell D. (2014). Pedestrian navigation with augmented reality, voice and digital map: final results from an in situ field study assessing performance and user experience. *J. Locat. Based Serv.* 8, 2 (2014), 75–96. https://doi.org/10.1080/17489725.2014.946975

Münzer, S., Zimmer, H. D., Schwalm, M., Baus, J., & Aslan, I. (2006). Computer assisted navigation and the acquisition of route and survey knowledge. Journal of Environmental Psychology, 26(4), 300–308. https://doi.org/10.1016/j. jenvp.2006.08.001

Yang, L., & Worboys, M. (2011). Similarities and differences between outdoor and indoor space from the perspective of navigation. *Poster Presented at COSIT*, *May 2014*, 05. http://nav.spatial.maine.edu/oispacewiki/images/c/c7/Cosit2011poster_ExtendedAbstract.pdf

Giudice N.A., Walton L.A., & Worboys M. (2010). The informatics of indoor and outdoor space: a research agenda. In *Proceedings of the 2nd ACM SIGSPATIAL International Workshop on Indoor Spatial Awareness*, pages 47{53. ACM, 2010

Delazari, L. S., Filho, L. E., Sarot, R. V., Farias, P. P., Antunes, A., & Dos Santos, S. B. (2018). Mapping indoor environments: Challenges related to the cartographic representation and routes. In *Geographical and Fingerprinting Data for Positioning and Navigation Systems: Challenges, Experiences and Technology Roadmap*. Elsevier Inc. https://doi.org/10.1016/B978-0-12-813189-3.00009-5

Brügger, A., Richter, K. F., & Fabrikant, S. I. (2019). How does navigation system behavior influence human behavior? *Cognitive Research: Principles and Implications*, *4*(1). https://doi.org/10.1186/s41235-019-0156-5

Chu, C. H., Wang, S. L., & Tseng, B. C. (2017). Mobile navigation services with augmented reality. *IEEJ Transactions on Electrical and Electronic Engineering*, *12*, S95–S103. https://doi.org/10.1002/tee.22443

Hurst, P., & Clough, P. (2013). Will we be lost without paper maps in the digital age? *Journal of Information Science*, *39*(1), 48–60. https://doi.org/10.1177/0165551512470043

Reilly, D., Rodgers, M., Argue, R., Nunes, M., & Inkpen, K. (2006). Marked-up maps: Combining paper maps and electronic information resources. *Personal and Ubiquitous Computing*, *10*(4), 215–226. https://doi.org/10.1007/s00779-005-0043-6

Dhar, D. B., & Chanda, B. (2006). Extraction and recognition of geographical features from paper maps. *International Journal on Document Analysis and Recognition*, *8*(4), 232–245. https://doi.org/10.1007/s10032-005-0010-9

Richardson, A. E., Montello, D. R., & Hegarty, M. (1999). Spatial knowledge acquisition from maps and from navigation in real and virtual environments. *Memory and Cognition*, *27*(4), 741–750. https://doi.org/10.3758/BF03211566

MacEachren, A. M. (1991). The role of maps in spatial knowledge acquisition. *The Cartographic Journal*, *28*(2), 152–162. https://doi.org/10.1179/000870491787859223

GOLDIN, S. E., & THORNDYKE, P. W. (1982). Simulating Navigation for Spatial Knowledge Acquisition. *Hum Factors*, *V 24*(N 4), 457–471. https://doi.org/10.1177/001872088202400407

Smets, N. J. J. M., Te Brake, G. M., Neerincx, M. A., & Lindenberg, J. (2008). Effects of mobile map orientation and tactile feedback on navigation speed and situation awareness. *MobileHCI 2008 - Proceedings of the 10th International Conference on Human-Computer Interaction with Mobile Devices and Services*, 73–80. https://doi.org/10.1145/1409240.1409249

Schöning, J., Cheverst, K., Löchtefeld, M., Krüger, A., Rohs, M., & Taher, F. (2009). Photomap: Using spontaneously taken images of public maps for pedestrian navigation tasks on mobile devices. *ACM International Conference Proceeding Series*.

Hergan, I., & Umek, M. (2017). Comparison of children's wayfinding, using paper map and mobile navigation. *International Research in Geographical and Environmental Education*, *26*(2), 91–106. https://doi.org/10.1080/10382046.2016.1183935

McMahon, D. D., Smith, C. C., Cihak, D. F., Wright, R., & Gibbons, M. M. (2015). Effects of Digital Navigation Aids on Adults With Intellectual Disabilities: Comparison of Paper Map, Google Maps, and Augmented Reality. *Journal of Special Education Technology*, *30*(3), 157–165. https://doi.org/10.1177/0162643415618927

Besharat, J., Komninos, A., Papadimitriou, G., Lagiou, E., & Garofalakis, J. (2016). Augmented paper maps: Design of POI markers and effects on group navigation. *Journal of Ambient Intelligence and Smart Environments*, *8*(5), 515–530. https://doi.org/10.3233/AIS-160395

Gartner, G. (2016). *Spatial Knowledge Acquisition with Mobile Maps, Augmented Reality and Voice in the Context of GPS-based Pedestrian Navigation: Results from a Field Test*. *0406*(March). https://doi.org/10.1559/15230406392107

Chen, C., & Li, X. (2020). *Spatial Knowledge Acquisition with Mobile Maps : E ff ects of Map Size on Users' Wayfinding Performance with Interactive Interfaces*.

Willis, K. S., Hölscher, C., Wilbertz, G., & Li, C. (2009). Computers , Environment and Urban Systems A comparison of spatial knowledge acquisition with maps and mobile maps. *Computers, Environment and Urban Systems*, *33*(2), 100–110. https://doi.org/10.1016/j.compenvurbsys.2009.01.004

Liu, B., Ding, L., Meng, L., & Liu, B. (2021). Spatial knowledge acquisition with virtual semantic landmarks in mixed reality-based indoor navigation reality-based indoor navigation. *Cartography and Geographic Information Science*, *00*(00), 1–15. https://doi.org/10.1080/15230406.2021.1908171

Alexander W . Siegel, & Sheldon H . White. (1975). The Development of Spatial Representations of Large-Scale Environments. *Advances in Child Development and Behavior*, *10*, 9–55.

Websites

1. https://www.dictionary.com/browse/efficiency

Appendix

A) Pre experiment survey questionnaire

I am an MSc Cartography student of Technical University of Vienna, Austria. As part of my MSc research thesis on the topic, "*Investigating the effects of mobile navigation services and paper maps on spatial knowledge acquisition of pedestrians in an indoor environment*", I am humbly appealing for your help by advocating to take part in my research experiment in Dresden. The experiment will be an indoor navigation exercise in the Altmarkt-Galerie of Dresden. The experiment is estimated to be completed within four to five hours. Please fill this questionnaire if you want help me by taking part in the exercise. Thank you very much for the help.

Name..... Mobile Number.....

1. DEMOGRAPHIC CHARACTERISTICS OF PARTICIPANTS			
S/N	**Questions**	**Answers**	**Responses**
101	Age	15 – 19	☐
		20 – 24	☐
		25 – 29	☐
		30 - 34	☐
		35 and above	☐
102	Gender	Male	☐
		Female	☐
103	Education	Basic School	☐
		High School	☐
		University (BSc, MSc, PhD, etc.)	☐
		None	☐
104	City	Freiberg	☐
		Leipzig	☐
105	Occupation	*State*	
2. KNOWLEDGE ABOUT THE STUDY AREA			
201	Have you visited Dresden before?	Yes	☐
		No *NB: if "No", skip #202*	☐
202	Have you been to Centrum Galarie?	Yes	☐
		No	☐
3. EXPERIENCE IN MAP USAGE			
301	Which of these maps have you used before?	Mobile navigation services (MNS)	☐
		Paper maps	☐
		Both mobile and paper maps	☐
		None of the maps above *NB: if none, then end of survey*	☐

302	Where have you used MNS?	Indoor environment *(e.g. Shopping Mall)*	[ ]
		Outdoor environment *(e.g. parks)*	[ ]
		Both environments	[ ]
303	Where have you used paper maps?	Indoor environment *(e.g. Shopping Mall)*	[ ]
		Outdoor environment *(e.g. parks)*	[ ]
		Both environments	[ ]

B) Post experiment questionnaire

1. Please select your group

a) Paper Map (PM) 2) Mobile Navigation Service (MNS)

2. On a scale of 1 – 10, how would you rate the overall experiment procedure?

Please state……..

3. How difficult was it in navigating back to the starting point of the route without using the map?

a) Very difficult b) Difficult c) Easy d) Very easy

4. Has the map helped you to fully acquaint yourself with the environment?

a) Yes b) neutral c) no

3) Navigation exercise for paper map group

PAPER MAP								
	With map				Without map			
SN	start time	end time	total minut	No. of stop	start time	end time	total minute	No. of stops
p1	*8:00*	*8:14*	*14*	*6*	*8:16*	*8:21*	*5*	*2*
p2	*8:23*	*8:34*	*11*	*5*	*8:36*	*8:40*	*4*	*1*
p3	*8:42*	*8:54*	*12*	*6*	*8:56*	*9:01*	*5*	*1*
p4	*9:03*	*9:18*	*15*	*7*	*9:20*	*9:27*	*7*	*3*
p5	*9:29*	*9:44*	*15*	*8*	*9:46*	*9:50*	*4*	*0*
p6	*9:52*	*10:01*	*9*	*3*	*10:03*	*10:06*	*3*	*0*
p7	*10:08*	*10:24*	*16*	*8*	*10:26*	*10:32*	*6*	*2*
p8	*10:34*	*10:44*	*10*	*4*	*10:46*	*10:51*	*5*	*2*
p9	*10:53*	*11:07*	*14*	*5*	*11:09*	*11:15*	*6*	*3*
p10	*11:17*	*11:29*	*12*	*4*	*11:31*	*11:35*	*4*	*0*
Total			128	56			49	14
Average			**12.8**	**5.6**			**4.9**	**1.4**
p = participant								

4) Navigation exercise for mobile navigation services group

MOBILE NAVIGATION SERVICE								
	with map				without map			
SN	start time	end time	total minut	No. of stop	start time	end time	total minut	No. of stops
pI	*12:00*	*12:04*	*4*	*0*	*12:06*	*12:20*	*14*	*5*
pII	*12:22*	*12:27*	*5*	*1*	*12:29*	*12:45*	*16*	*7*
pIII	*12:47*	*12:53*	*6*	*1*	*12:55*	*13:15*	*20*	*9*
pIV	*13:17*	*13:20*	*3*	*0*	*13:22*	*13:31*	*9*	*3*
pV	*13:33*	*13:37*	*4*	*0*	*13:39*	*13:50*	*11*	*4*
pVI	*13:52*	*13:56*	*4*	*0*	*13:56*	*14:08*	*12*	*5*
pVII	*14:10*	*14:15*	*5*	*0*	*14:17*	*14:30*	*13*	*5*
pVIII	*14:32*	*14:35*	*3*	*0*	*14:37*	*14:49*	*12*	*4*
pIX	*14:51*	*14:55*	*4*	*1*	*14:57*	*15:07*	*10*	*4*
pX	*15:09*	*15:15*	*6*	*2*	*15:17*	*15:30*	*13*	*6*
Total			44	5			130	52
Average			**4.4**	**0.5**			**13**	**5.2**
p = participant								