University of Zurich[UZH]

# Representation of Local Landmarks in Bicycle Navigation Applications and their Effect on Learning Planned Routes

GEO 511 Master's Thesis

**Author**
Florian Sturzenegger
15-721-863

**Supervised by**
Dr. Tumasch Reichenbacher
Prof. Dr. Sara Irina Fabrikant

**Faculty representative**
Prof. Dr. Sara Irina Fabrikant

30.06.2022
Department of Geography, University of Zurich

**Abstract**

Bicycle navigation is one of the most important modes of transport in modern society with various advantages for traffic and health reasons. It is likely, that the importance will further increase in the future. A crucial aspect when riding a bicycle is navigation and orientation, especially with focus on spatial route learning. The reason therefore is, that navigation assistants, for instance mounted navigation tools, are not as common and practical as in comparison when used in other modes of transport. The learning and remembering of a specific route in advance of a bicycle trip is therefore a convenient tool to make bicycle riding easier and more attractive and to know the course of the route, which is planned to be completed. This, because navigation and information stops can be avoided, which results in less driving time and less driving effort. A possible concept on how to improve this route learning, is the integration of landmarks into a map application, more specifically into a specific route, as guidance and helping points, which could then increase the spatial route learning process. This very inclusion is looked at in more detail in this master thesis through a conducted navigation experiment with 39 participants at the University of Zurich, where the effect of such displayed landmarks as symbols and pictures is compared with no display of landmarks. The hypotheses are, that the spatial learning process can be improved when landmarks are shown and that the display of a real-world picture of a landmark is more helpful to the spatial learning process than an abstract symbol of a landmark. The test set-up consisted of three groups, the first of which was shown only the route, the second the route with selected landmarks as symbols and the third the route with selected landmarks as pictures. The participants in all groups were then asked to remember the route and its course and to name the correct turns by playing the route on a video, while they simulated the bicycle ride on a bicycle ergometer.

Under these specific experiment conditions and with the measured parameters in this study, regarding the two hypotheses, there could be no significant improvement of the spatial learning process seen, when landmarks have been illustrated in comparison with no display of landmarks. Additionally, no significant difference could be found in between the difference of displayed abstract symbols or displayed real-world pictures of those landmarks. Although no significant data could be found in this experiment, small tendencies and minor differences between the groups could be found. Additionally, interesting data regarding the decision time and the confidence of the participants between the different three groups could be found. This data shows tendencies that the decision time for the participants which had landmark visualised either as symbols or pictures was shorter than for the participants who had no landmarks visualised. Similar data tendencies could be found that the participants having landmarks displayed as symbols or pictures, were more confident with their navigation decisions. There are also indications that landmarks in the beginning of the route helped more in the spatial learning process and the navigation in comparison with the ones visualised at the end. Even though no significant data could be found, indications could be gathered, that some of the data points in a similar direction than much of the current literature, so that the visualisation of landmarks can contribute to navigation and spatial learning and that further in-depth research in this area would be useful.

**Keywords**

Navigation, Landmarks, Bicycle, Spatial Knowledge, Spatial Learning Process

# Contents

# Acknowledgement

At this point, I would like to take the opportunity and thank all the individuals who helped me throughout the whole process of this master thesis and who all contributed a lot to this work.

In the beginning, I would like to give a huge thank you to my supervisor Dr. Tumasch Reichenbacher who accompanied me during the whole process of this master thesis and helped me with important tips and discussions. From my side, it was very much appreciated that the door to ask something was always open. Any problems that arose during the work could be discussed immediately and together a solution could be found. Additionally, I would like to thank Prof. Dr. Sara Irina Fabrikant for her help in the beginning and in the course of the work. I really valued the friendly and open way we all worked together. Also big thanks to the Department of Geography of the University of Zurich for the whole study room setting and all the hardware I could use. Additionally, I would like to thank the Institute of Physiology of the University of Zurich for the bicycle ergometer which I could borrow for the course of my study.

Of course, I would like to thank all the people who participated in my study and helped me gaining this interesting data. This master thesis could only be done through the valuable help of all those participants. In addition to that a big thank you to the people who participated in the pilot studies and helped me improve the process for the main conduct of the study.

Finally, I would like to thank my family, friends and my girlfriend a lot, who all helped me many times with this master thesis through ideas, discussions but also with mental and motivational support.

# Abbreviations

| | |
|---|---|
| **SBSOD** | Santa Barbara Sense of Direction (spatial ability pre-test) |
| **Without group** | Participants in the study under the condition, where only the course of the route was visualised without any landmark information. |
| **Symbols group** | Participants in the study under the condition, where in addition to the course of the route, landmarks as abstract symbols were visualised. |
| **Pictures group** | Participants in the study under the condition, where in addition to the course of the route, landmarks as real-world pictures were visualised. |

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# 1 Introduction

## 1.1 Motivation and Problem Situation

Imagine the situation where you get up in the morning to ride on your bicycle to an appointment in an area of your hometown you spatially do not know very well. Therefore, you must probably check an application on your smart phone or computer to get an idea which route to take to reach that specific destination. Consequently, you grab your smart phone and look up the route you must take by entering your current location and the destination you would like to reach. Before getting on your bicycle, you try to remember the displayed route and all the turnings you must take. But almost every bicycle rider knows the problem that sooner or later on your route you are not sure which way you have to go to reach your destination. Since the route is not a straight line and you have to remember turnings, road changes and so on, it is very difficult to remember every route detail. In addition to the route information, you want to access, you also need to pay attention to the traffic and your surroundings. To avoid harming yourself or any other road user, you must leave the street and get off your bike to check the route again on your smart phone. This is generally time consuming and annoying, resulting that it would be a lot more efficient if you could remember the planned route without the need for getting off the bike. Additionally, such a situation can be accompanied with a positive or negative stress situation, as sometimes you are required to be somewhere at a specific time, or you must hurry to get somewhere as soon as possible. Therefore, it would be helpful to find a way to better memorise the route and integrate certain tools into a routing application, resulting in the fact that the route could perhaps be driven without annoying stops.

One possibility is to consider a mounted navigation tool for the handlebar of the bicycle, which for instance can hold a smart phone or another advanced navigation aid hardware. This could possibly be a touchscreen attached to the handlebar (Savino et al., 2021, p. 2). Navigational systems which are using audio input to give navigation information would also be a slightly more futuristic possibility, have it been already used in research (Lander et al., 2017, p. 2725). Smart-glasses, which are working with augmented reality, are hardware specific and partly not yet mature for the general population, partially due to its complexity (He and Zhao, 2020, p. 1-7) and (Diaz et al., 2018, p. 1-8). Such tools can be named "Virtual Personal Assistant", where bicycle navigation can be supported with various tools (Matkovic and Weis, 2020, p. 1-2). Also performance data hardware on the bike itself could improve bicycle navigation, for example with measuring speed data for further safety and efficiency (Matkovic and Weis, 2020, p. 1-2).

One important point when discussing about such assisting tools is that it can be stated that during cycling the constraints for the person on the bicycle are quite high, due to the fact that the surroundings have to be looked at carefully and the hands and feet are active in this process (Marshall et al., 2016, p. 218). For the different means of transport the following Figure 1 by Marshall et al. (2016) links the means of transport with the constraints illustrating that cycling shows strong constraints (Marshall et al., 2016, p. 218).

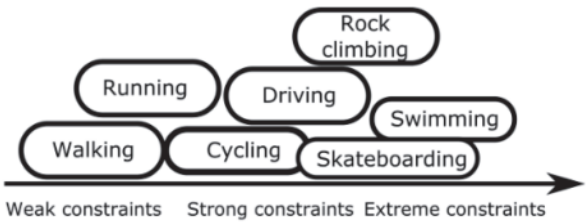



Figure 1: User constraints for different means of transport (Marshall et al., 2016, p. 218)

Alternatively to those above mentioned systems, when thinking on how to achieve the improvement of the spatial route learning process and also the improvement of a routing application, the topic of landmarks comes up (Albrecht and von Stülpnagel, 2021, p. 22-26). The use of landmarks shows that it is possible to increase wayfinding abilities and spatial orientation (Yesiltepe et al., 2021, p. 405). Unfortunately, the topic of landmarks is not as simple as that, because other factors like the location of the landmarks can play an important role to help someone in a wayfinding process (Chan et al., 2012, p. 2). In other words, if the landmark is located at a prominent spot it has a different effect than if it would be located at an unimposing location (Lynch, 1960, p. 79). Not only the position but also the appearance of landmarks function as a key role. In a study by Yesiltepe et al. (2021) various papers show that both the salience and visibility of landmarks play a crucial regarding the question on how helpful they are in the topic of spatial learning and spatial wayfinding (Yesiltepe et al., 2021, p. 374-388). On the one side landmarks can help improve the cognitive map of individuals (Cheng et al., 2018b, p. 1-3). Nevertheless, the cognitive load for the human being, which entails such additional information, has to be looked at carefully (Sorrows and Hirtle, 1999, p. 37). An ongoing study at the University of Zurich, which showed preliminary results, examines the performance in combination with the cognitive load through additional landmarks, as there is a certain peak at which people perform the best (Cheng et al., 2018a, p. 1).

Looking again at the problem situation and the motivation further up to increase the spatial route learning process of bicycle riders it has to be stated again that the using of landmarks is not the only possible solution but can be a very valuable addition. Thus, various navigation tools and orientation help ideas as for example "as-the-crow-flies" navigation, where the approximate destination via a arrow is shown at all times, can also be helpful in bicycle driving (Savino et al., 2021, p. 2) and (Savino et al., 2020, p. 1). This can be used as an alternative to the well-known "turn-by-turn" instructions (Savino et al., 2020, p. 1). The former could be possibly better readable for drivers. Other ideas include possible audio guided navigation tools or different hardware and software, which could help people while navigating (Albrecht et al., 2016, p. 124) and (Diaz et al., 2018, p. 1-8). It is probably also possible that not only either such hardware tools will be further promoted but that it rather could be also a co-existing solution with the additional help of landmarks in navigation. Bicycle navigation forms an important part of our society and works as a pollution friendly and practical mobility tool (Salmeron-Manzano and Manzano-Agugliaro, 2018, p. 1-3). Consequently, the improvement of bicycle navigation and its tools have their justification to be examined to

promote bicycle navigation in the future even more. In this paper, the focus is not on hardware navigations aids, but on the inclusion of local landmarks, and to return to the question posed at the beginning, whether the inclusion of these very landmarks in a route application can increase the route learning process and how they need to be symbolised?

## 1.2 Structure of the Thesis

In this subsection a brief overview on how this master thesis is structured is given. Additionally it is also illustrated in the graphic below. The first part of the thesis was an introduction into the thematic of the thesis, to give the reader an idea on what the master thesis, respectively its topic is about. In other words, what the problem situation and motivation is. This section is then followed by the formulation and explanation of the aims and the hypotheses of the thesis. In addition to that the two research questions are illustrated which then should be answered in the course of the work, more specifically in the results and the discussion part. Following this, the literature review attempts to give a broader picture about the state of the research to have a deeper understanding about the topic of this master thesis. As this master thesis is embedded in different areas, for instance landmark and bicycle navigation, the literature review deals with some partially different sub areas, which however all come together in the work and should form the basis of this thesis. Followed by the literature review, the method for the master thesis is explained in more detail, focusing on the specific illustration on how the experiment was conducted. Shortly thereafter, the results of this conducted experiment are revealed and displayed. The described and illustrated results will then be debated in the discussion part, where the results are linked with the literature background mentioned above. Additionally, the two stated research questions are being answered in this part of the work. The conducted study is also being critically examined in this section of the work. The end of the thesis builds the conclusion, where the content of the thesis is summarised shortly and also an outlook into future research areas regarding this topic is given.

The above explained structure of the master thesis is shown here in Figure 2 to ensure faster orientation.

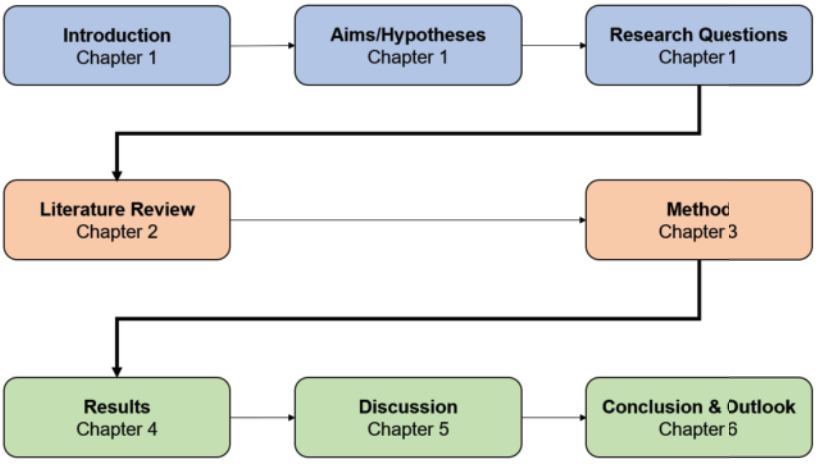



Figure 2: Structure overview of this master thesis

## 1.3 Aims

The main aim of this thesis is to find out whether the spatial learning process of a planned bicycle route in an urban environment can be improved, in regards of better memorability, by displaying local landmarks in a routing application (e.g. Open Street Map, Google Maps, Apple Maps and more) and by displaying them with either simple, abstract symbols or real-world pictures. If the learning process of such a planned route could be improved, it would be a valuable contribution for future bicycle mobility in urban environments. The short scenario outlined in the introduction, i.e. the need for stopping to check the route on your smart phone, could perhaps become obsolete if the landmark display in a routing application and their symbolisations could improve the spatial learning process. Through the possible improvement of navigation during bicycle riding, more people could under certain circumstances be motivated for bicycle riding as this mode of transport would therefore be made more appealing to people.

## 1.4 Hypotheses

The first main hypothesis of this master thesis is that the spatial learning process can be improved, when specific local landmarks are shown in addition to the exact planned route, or in other words the course of the route, resulting in less direction change errors at decision points when navigating this same planned route. The learning process can be modified depending on the chosen symbolisation type, e.g. simple, abstract symbol or real-world picture. The second main hypothesis is, that a real-world picture, having a higher degree of realism than a more abstract symbol, leads to an increased spatial learning of the planned route compared to an abstract symbol, meaning that the route can be memorised better, resulting in less errors at decision points for changes of direction. Those two hypotheses are illustrated below shortly. H0 is representing the null hypothesis, and H1 is representing the alternative hypothesis (Storrer, 2004, p. 224-233). Later in the thesis when performing statistical analysis, the H0 hypothesis for both gets rejected, when the p-value is smaller than 0.05. This is the case as the significance level in this thesis is chosen as 0.05 ($\alpha$). So statistically it can be assumed that if the resulted value of the statistical test is smaller than the defined significance level, the alternative hypothesis has to be accepted, or in other words, that it is likely that the alternative hypothesis is valid. In the case of the significance level of 0.05 it means then that the probability of making a Type 1 error, accepting the alternative hypothesis even though it would not be valid, is 5 % (Travers et al., 2017, p. 208-215) and (Storrer, 2004, p. 224-233).

**Hypothesis 1**

H0: The spatial learning process cannot be improved when local landmarks are shown in addition to the exact planned route, thus not resulting in fewer direction change errors at decision points.

H1: The spatial learning process can be improved when local landmarks are shown in addition to the exact planned route, resulting in fewer direction change errors at decision points.

**Hypothesis 2**

H0: Displayed real-world pictures of local landmarks do not improve or weaken the spatial learning process of a planned route in comparison with simple symbols of local landmarks.

H1: Displayed real-world pictures of local landmarks do improve the spatial learning process of a planned route in comparison with simple symbols of local landmarks.

## 1.5 Research Questions

The following two research questions emerged from the above stated aims and hypotheses of this master thesis. Those two research questions will be answered in the course of the work.

**Research Question 1:**
How does the representation of local landmarks for a planned, urban bicycle route in a map application improve a priori spatial learning?

The first research question addresses the influence of landmarks to improve a priori spatial learning in comparison with no landmark information displayed on the map. This research question is derived from the Hypothesis 1 above. It investigates whether an improvement of the spatial learning process can be shown by such landmarks both displayed either or as real-world pictures and abstract symbols.

**Research Question 2:**
How does the symbolisation of local landmarks in a map application, in more detail simple, abstract symbols and real-world pictures, influence their memorability and also differ with their effect on the a priori spatial learning?

The second research question examines the different symbolisations, specifically simple, abstract symbols and real-world pictures, and how those differ in the improvement of the a priori spatial learning process. This research question is derived from the Hypothesis 2 above.

# 2 Literature Review

In this chapter the scientific background of this master thesis is illustrated and explained, and an extended literature analysis is being done. As already mentioned in the introduction section, different subtopics get displayed and explained here a bit further in detail, since all those different areas converge in the overall thematic of this work. The literature review chapter is structured as following that first the terms of navigation, wayfinding and routing are discussed, followed by a focus on bicycle navigation. After that, the thematic of landmarks is examined more closely also with the subdivision into local and global landmarks. Subsequently, the spatial learning process and the term of spatial orientation is explained and analysed. The topic of spatial learning is then linked to the thematic of design and symbolisation of landmarks in map applications. Last but not least an inclusion into the thesis is illustrated. All those small chapters form the basis of the scientific frame for this thesis, resulting in the fact that this literature background then forms the basis of the method of this master thesis.

## 2.1 Navigation, Wayfinding and Routing

An important pillar of this work is the theory about navigation and routing. Therefore, that it would make sense to define and explain those terms in this subsection and give the reader an overview. Navigation forms a part of our everyday life and people are confronted with navigation in many different areas of their life. Be it partly because of this, that navigation interaction with the space and environment is important (Ahmadpoor and Shahab, 2019, p. 1). Just to mention a few situations, we have to navigate around a building, in a room or into a different place of the city. It also forms an important part with the connection to the people we know and would like to meet in person, as we are not always at the same place and have to navigate to each other (Montello and Sas, 2006, p. 1). Navigation not only plays an essential role in the life of human beings, also in the world of animals different forms of navigations and tools which are used for that specific process can be seen (Yang, 2020, p. 1-2). So for example various animals use the sun for navigation tasks and also landmarks are being used by animals for navigational purposes, such as whales and pigeons (Yang, 2020, p. 1-3).

Literature splits up navigation into two sub parts, in more detail on the one hand wayfinding and on the other hand locomotion (Montello and Sas, 2006, p. 2). Firstly, wayfinding describes the planning process of the route, so in other words the finding of the actual route one would like to travel. Secondly, locomotion refers to the actual moving process which was planned during the wayfinding process before (Montello and Sas, 2006, p. 2). It is referring to the task in the real world where different problems have to be solved, like moving on the ground, avoiding obstacles and so on (Montello, 2005, p. 257-294) in (Montello and Sas, 2006, p. 2). So navigation includes both the setting of a specific route and also the guidance of that specific defined route (Hofmann-Wellenhof et al., 2003, p. 2). A similar term which is often encountered in the literature is wayfinding. Golledge (1999) defines wayfinding in a very familiar way as the definition of navigation, as it is defined as the procedure to define and to follow a specific route or path (Golledge, 1999, p. 6). The terms of navigation, wayfinding and routing are very closely related, as routing is associated to both of the mentioned sub parts above, as it is including aspects on the route planning and the actual guiding of the route (Hofmann-Wellenhof et al., 2003, p. 2). An important aspect though is that when wayfinding or navigating through an environment people use cognitive skills to use and understand a cognitive map of this environment (Haig, 2019, p. 14).

Navigation is not only associated with a vehicle but often it is being a part of the navigation task (Hofmann-Wellenhof et al., 2003, p. 2). Not surprisingly it forms also a huge part in the bicycle mode of transport, which is examined in more detail in the next chapter is the specific mode of transportation studied in this thesis.

## 2.2 Bicycle Navigation

Mentioned in the upper section another important thematic point and part of this master thesis is the bicycle navigation which is worth taking a closer look at. Bicycles have always been a part of mobility and are becoming an increasingly popular mean of transport because of various reasons. The bike has the possibility to replace the car or the public transport and become even more substantial in the future (Savino et al., 2021, p. 1).

The sustainable aspect, split up into the three sub aspects, the economical, the social and the ecological sustainability, is hereby becoming increasingly important (Spadaro and Pirlone, 2021, p. 1). In addition to that, the sensitisation of people to a more healthier lifestyle and also some changes in mobility due to the Corona-Virus crisis led to an increase in bicycle mobility (Savino et al., 2021, p. 1). It is further important to mention that there has also been an increase in electrified bike mobility in recent years, which is also a high promotional factor for electric bike mobility. Those short called, E-Bikes have the advantage on being a healthy and fast mean of transport, similar to a non-electric bicycle, but somehow more advanced (Salmeron-Manzano and Manzano-Agugliaro, 2018, p. 3). More advanced in a sense that people still benefit from the fact that a so-called E-Bike is practical and can be parked at the same spots as a non-electric bicycles and traffic can be bypassed similar or more easily than a non-electric one. Moreover, people still exercise and look after their health (Salmeron-Manzano and Manzano-Agugliaro, 2018, p. 3).

In addition to health aspects, it is also important to state that safety for bicycle riders of any age is crucial. Various safety tools and instruments, for example warning systems for collisions are being investigated and implemented (Matviienko et al., 2018, p. 1-13). Coming back to the scenario in the beginning where the route cannot be remembered by a specific person, a possibility could be, that route navigation during the driving is being done. This can be dangerous and an improved spatial learning of the route could make the use of a navigation tool during the cycling process obsolete and therefore maybe make bicycle navigating safer. This could be assumed as a study in India looked at safety aspects and the use of a smart phone during motorcycling. It could be showed that near misses and accidents can have a relation to the use of smart phones during driving (Adhikari et al., 2021, p. 117). Even though the motorcycle is not the same vehicle as a bicycle there are some similarities in the manner of how the vehicle is being driven.

In Switzerland bicycle mobility is increasing and also the section of the slow-moving mobility with pedestrian and bicycle mobility (UVEK (Eidgenössisches Departement), 2018, p. 1-8). So between the year 2010 and 2040 an increase of 32 % is expected for this section (UVEK (Eidgenössisches Departement), 2018, p. 1). That the bicycle plays a crucial role can be seen in the following graphic. It can be concluded that the focus on bicycle navigation in this master thesis is justified, as this mode of transport is likely to increase in the near future.

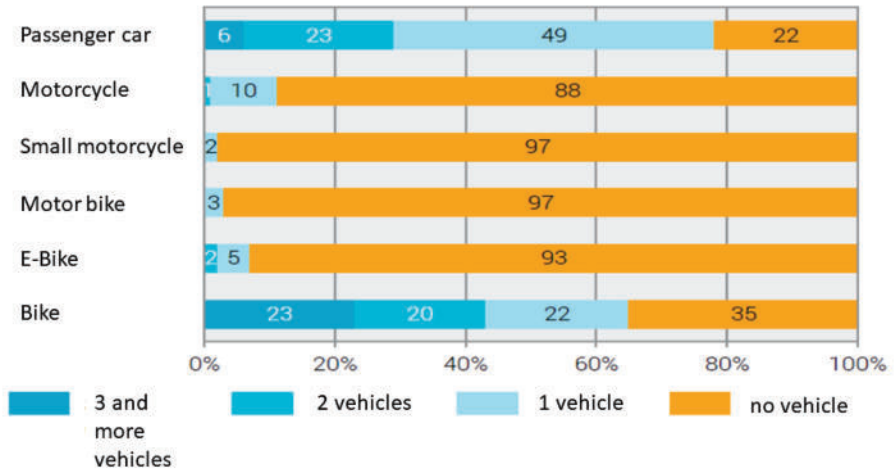



Figure 3: Overview about owned vehicles per household in Switzerland (2015) (UVEK (Eidgenössisches Departement), 2018, p. 3) (translated into English)

Figure 3 shows for each category how many vehicles are owned per household for the year 2015. The data are collected by the UVEK, the federal department of the environment, transport, energy and communications of Switzerland. It can be seen that approximately a third of the households of Switzerland are in possession of at least one bicycle or electric bicycles citep[p. 3]UVEK2018. Resulting that those numbers almost match with the numbers for the passenger cars. This graphic clearly illustrates the importance of bicycle mobility in the present and in the future and why mobility and therefore also navigation issues are worth looking at for this specific mode of transport.

## 2.3 Landmarks

As the concept of landmarks, their definition and their influence on spatial learning are crucial aspects in this master thesis, the idea and definition of landmarks are explained here a bit further in detail. The definition of landmarks is not as simple and clear as maybe one can think of (Yesiltepe et al., 2021, p. 369-410). Many different ideas for a specific definition exist and therefore, it is important to sort those ideas. An important question to define what a landmark exactly means, is what can be included in the definition of a landmark. So maybe not a single decision can be given but certain aspects can be looked at to give an approximate definition (Sorrows and Hirtle, 1999, p. 39).

A very early approach at defining and mentioning landmarks gave Lynch in the year 1960. It was defined that landmarks function as a way of a point-reference in a city or an environment (Lynch, 1960, p. 49). On the one hand, there are specific landmarks which are far away and more distant and can already

be seen from further away, and on the other hand, also more local and closer landmarks which can be only seen from closer distances and specific angles exist (Lynch, 1960, p. 49). In addition to that, landmarks should have a unique characteristic, in more detail if they have a distinct form, are located spatially notable or are contrasting with the background (Lynch, 1960, p. 78, 79). Lynch (1960) mentioned an example to illustrate what could be understood as a landmark and displayed the example of the "Piazza San Marco" in Venice. Characteristics, which were mentioned are the clear contrast to the surrounding environment, the shape which can be recognized well and smaller landmarks in this area as the dome or the palace (Lynch, 1960, p. 78). The two pictures in Figure 4 show the "Piazza San Marco" on the left side how it was displayed in the paper by Lynch (1960) and on the right side a coloured pictured on how it looks from the ground. The tower and the building next to it are visible which can be understood as landmarks.

(a) Piazza San Marco (Lynch, 1960, p. 79)

(b) Piazza San Marco coloured (Unsplash (Alessio Furlan), 2022, p. 1)

Figure 4: Piazza San Marco in Venice as an example of a landmark(s) by Lynch (1960)

The idea that any decision point in space can be seen as a landmark is one way to define this concept (Siegel and White, 1975, p. 9-55) in (Sorrows and Hirtle, 1999, p. 39, 40). Chronologically later, the definition from Lynch was confirmed by Sadalla et al. (1980), that landmarks can be seen as specific spatial reference points (Sadalla et al., 1980, p. 516). According to this definition, a huge number of objects can serve as a landmark. The idea that any decision point in space can be considered as a landmark is one way to define this concept (Siegel and White, 1975, p. 9-55) in (Sorrows and Hirtle, 1999, p. 39, 40). On the other hand there are concepts which are saying that not every possible point is a landmark, but rather only some specific points or things can be seen as landmarks (Sorrows and Hirtle, 1999, p. 39). Specific characteristics, as mentioned in the example above of the "Piazza San Marco" in Venice, like shape, colour, prominence should be present to define an object as a landmark (Bestgen et al., 2017, p. 179-183). With time some more specific definitions and also somehow more restricting definitions emerged which will be explained a bit closer in the following part. A more detailed classification of landmarks is the division into visual, structural and cognitive landmarks by Sorrows and Hirtle (1999). The first category called a **"Visual Landmark"** is a landmark which is visibly striking and eye-catching. This can be due to its colour, shape or texture, its spatial location or also the contrast with the objects or the environment around it (Sorrows and Hirtle, 1999, p. 45, 46). This is very similar to the above given definition by Lynch (1960), where also about a unique appearance and the placement in the surrounding is being talked (Lynch, 1960, p. 78, 79). The second category defined is called a **"Cognitive Landmark"** where not the visual characteristic is important, but rather its meaning in a cultural or historical sense. In other words, the essence of the object or building is

important and therefore it can also be that this kind of landmarks are individually different (Sorrows and Hirtle, 1999, p. 46). The third and last categorisation is called a **"Structural Landmark"** where the function of the object in comparison with its surrounding is the decisive factor. So the conspicuousness and also approachability are two important factors in this category (Sorrows and Hirtle, 1999, p. 46). These three categories should not be viewed exclusively separately, as a landmark can often be assigned to two or three of these categories .(Sorrows and Hirtle, 1999, p. 46)

As the definition of landmarks is really broad and not as simple as maybe thought, another interesting definition approach to the term of landmark is given. Building on the concept of the three categories, a distinction can be made between visibility and salience (Yesiltepe et al., 2021, p. 371-405). Firstly, when talking about how close an object can be related to be defined as a landmark is its **"Visibility"**. This can be looked at how good a specific object or feature can be seen from the distance or also from a specific angle. Hereby, the differentiation between local and global landmarks is being done (Yesiltepe et al., 2019, p. 1-4). This is explained a bit further in the following subsection (Yesiltepe et al., 2021, p. 374). Secondly, the term of **"Saliency"** of the specific object is important to define it as a landmark. Here, different parameters can be used to define the ability of an object to act as a landmark. Such parameters can be the area, the shape or the colour of the object (Yesiltepe et al., 2021, p. 404). Generally, structural and visual saliency can be differentiated (Yesiltepe et al., 2021, p. 381, 404, 405). The former describes the importance of a landmark's position and the latter describes the noticeability of a landmark (Yesiltepe et al., 2021, p. 381). There is also the term of cognitive salience, where the significance of the feature is important and the interpretation of it (Yesiltepe et al., 2021, p. 381). The saliency of objects or landmarks have been investigated including their definition aspects regarding the term of landmarks. In the study by Albrecht and Stülpnagel (2021) the saliency of landmarks have been looked at more closely or in other words, the definition of saliency of the landmarks was forming a crucial step in their study (Albrecht and von Stülpnagel, 2021, p. 8-11). For example, the study found that under the situation of not having the knowledge in which direction to move forward, the participants chose the direction of the landmark which was visually salient. Even though there was no clear interpretation for this, this seems to be interesting and underlines the importance of salience (Albrecht and von Stülpnagel, 2021, p. 22-24). In a paper by Keil et al. (2020) the point of the location of a landmark was discussed, respectively it was looked at where the features were located, so for example at a decision point or a potential decision point or even along the route (Keil et al., 2020, p. 3). This illustrates also the idea of the location of a landmark feature.

Overall it can be difficult to give a clear definition of a landmark, however those mentioned characteristics can help to define it (Yesiltepe et al., 2021, p. 405-407) and (Sorrows and Hirtle, 1999, p. 45-46). Those important aspects are not the only possibility to define landmarks and their different types. The next chapter explains how landmarks themselves can be distinguished from each other or if there are certain categorisations.

### 2.3.1 Global and Local Landmarks

Resulting from the concept of visibility which has been explained above, a very common differentiation between the landmarks is to categorise them into global and local landmarks (Yesiltepe et al., 2019, p. 1). This concept is shortly evaluated a bit further here. Firstly, global landmarks represent landmarks which can be seen from a further distance. So for example a high tower or also mountains can be seen as global landmarks (Steck and Mallot, 2000, p. 69). Secondly local landmarks represent landmarks which can only be seen from a closer distance and not as global landmarks from far away (Steck and Mallot, 2000, p. 69).

Important to mention is that both of those landmark types can work as a navigation aid (Steck and Mallot, 2000, p. 69, 70). A study by Credé et al. (2020) looked at how global landmarks can support the spatial knowledge acquisition, especially when those are located along the route (Credé et al., 2020, p. 6-8). Also regarding local landmarks and their contribution to spatial knowledge acquisition and as a navigation aid, the effect of such local landmarks have been investigated (Raubal and Winter, 2002, p. 243-259). So not only global landmarks can contribute in wayfinding and navigation but also local landmarks (Steck and Mallot, 2000, p. 81. 82). To illustrate the difference between local and global landmarks a study by Credé et al. (2019) was being conducted and visualised. The setting used in their study shows what is meant with a local and with a global landmark, and is visualised in their paper as followed (Credé et al., 2019, p. 199). On the one hand an example for the global landmarks were two tall green buildings in the far distance, but still visible for the participants, on the other hand an example for the local landmark was a bright yellow building on the corner straight next to the road (Credé et al., 2019, p. 199). Even though this classification between landmarks can be useful, further research needs to be done about the distinguishing between global and local landmarks (Yesiltepe et al., 2021, p. 374). As one can see, the definition of landmarks is not as simple as thought and different definition approaches and ideas can be distinguished. This chapter had the idea to give a small overview on specific aspects, on how the definition could be structured or in other words, which important characteristics could be used to define landmarks.

## 2.4 Spatial Learning Process and Spatial Orientation

After giving an overview about how different approaches exist to define a landmark, it is important to have a closer look at the spatial learning process and in addition to that, how landmarks can influence this spatial learning process. To fully understand the spatial learning mechanism the medical and anatomical aspect must be looked at more closely. Different areas of the human brain have dissimilar functions when looking at the process of spatial learning and navigation (Solari and Hangya, 2018, p. 2199). Namely three important regions of the human brain form an important aspect, the hippocampus, the posterior parietal cortex and the retrosplenial cortex (Solari and Hangya, 2018, p. 2213). In Figure 5 where a graphic by Solari and Hangya (2018) is shown areas with the different functions regarding the spatial learning and navigation are shown. The hippocampus plays a crucial role in the spatial memory function, when objects and the environment (e.g. landmarks and route) have to be remembered (Dahmani and Bohbot, 2020, p. 2). In other words the process of commemorating the link between different objects, for instance landmarks, can activate and use the hippocampus (Bohbot et al., 2004, p. 422).

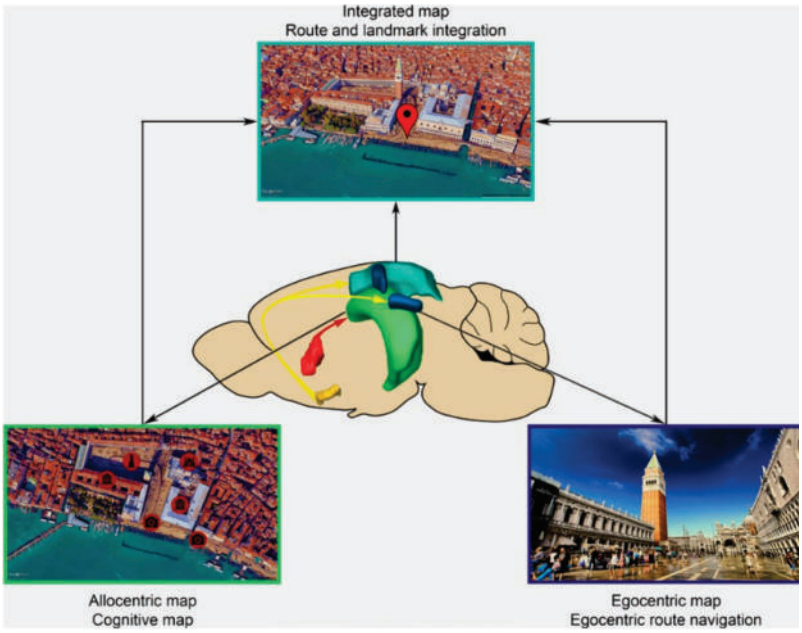



Figure 5: Important areas functions of the brain in terms of spatial learning and navigation (Solari and Hangya, 2018, p. 2213)

In Figure 5 there are different parts of the brain visualised which play an important role in the spatial learning process and navigation. The green part is the hippocampus, the dark blue parts is the posterior parietal cortex and the teal part is the retrosplenial cortex (Solari and Hangya, 2018, p. 2201). The graphic links these different regions of the brain with specific information processing. The region of the hippocampus is responsible for the function and presentation of allocentric information and is also in addition that building the cognitive map (Solari and Hangya, 2018, p. 2201). The posterior parietal cortex serves for the egocentric map and the route navigation. Both of those functions then work together to form the integrated map which is built from those two, resulting in the route and landmark information (Solari and Hangya, 2018, p. 2213). Another important aspect resulting out of the medical circumstances is the cognitive load or the working memory load. Visualising landmarks or other objects and having graphics in a map lead to an increase in the cognitive load, respectively of the working memory (Setlur et al., 2010, p. 1). Especially the number of visualised objects, for instance landmarks is an important parameter which can lead to an increased cognitive load (Cheng et al., 2018b, p. 1). Prior results of a still ongoing research claim that the optimal number of displayed landmarks is five, with no added cognitive load. So the cognitive load plays a crucial role in the effectiveness of landmarks (Cheng et al., 2018b, p. 3).

### 2.4.1 Spatial Learning Process Linked with Displayed Landmarks

Having the spatial learning process then linked with displayed landmarks in a map, presents an interesting topic which has been partly investigated in various studies and will be examined in more detail here. The topic of understanding such processes as spatial learning and spatial knowledge acquisition is a huge research area, because it combines different scientific areas, as for example neuropsychology, anatomy and geography (Solari and Hangya, 2018, p. 2199-2230) and (Bohbot et al., 2004, 418-425). It is important to understand how the cognitive mechanisms of the users' work with such displayed features and with geographic information

displays (Thrash et al., 2019, p. 6). The question on how the display of landmarks in a route or map application can increase the spatial learning process, is explained in the following.

The literature in this area provides results that displayed landmarks can have a beneficial effect on the improvement of spatial knowledge, i.e. they can improve the spatial learning process (Li, 2020, p. 432). For instance, a recent study by Löwen et al. (2019) investigated in their study if the presentation and highlighting of local and global features in a map design improves the process of spatial learning (Löwen et al., 2019, p. 11-13). It has been found, that local features and global features have a positive influence on route knowledge, respectively on the survey knowledge (Löwen et al., 2019, p. 13). Another very recent study by Ben-Elia (2021) obtained similar data, as he investigated the difference between the spatial learning through a map or through guided navigation (Ben-Elia, 2021, p. 6). It could have been found that the spatial learning process is improved when a map is studied in advance, respectively the memorising of landmarks could be better, after the studying of the map (Ben-Elia, 2021, p. 9). A third study looked at a very similar topic as it was investigated, if landmarks, which are set by people themselves, help in spatial orientation. Even though it could be identified that those landmarks can have an adverse effect for the mental map, the overall spatial orientation increased when landmarks have been shown (Von Stülpnagel et al., 2014, p. 1711). However, not only in studies regarding the real world, but also in those focusing on virtual environments landmarks can play an important rule. As back in 1999, Vinson for example published some basic ideas on how such landmarks could be represented in virtual environments in order to increase spatial knowledge. It is important to note that these are "rules of thumb", but the rules still seem to make sense (Vinson, 1999, p. 278-285).

For instance, Guideline one states: "It is important that the virtual environment contains multiple landmarks" (Vinson, 1999, p. 280). Or another example is Guideline ten, which states: "Place landmarks on major paths and at path junctions" (Vinson, 1999, p. 282). This is also supported by a study of Keil et al. (2020) where it has been found that the further a landmark is away from a decision point, the less relevant that landmark is for the spatial route learning process (Keil et al., 2020, p. 15). Also the design aspect on how landmarks should be visualised was investigated (Vinson, 1999, p. 278-285). Nevertheless, when discussing the influence of landmarks on spatial learning and navigation, there are also critical voices, that the effect of landmarks regarding navigation and spatial ability is exaggerated, based on the fact, that not enough weight is given to other factors and also that the concept of landmarks is not clearly enough defined (Montello, 2017, p. 193,194). Despite some critics, many studies demonstrate a support for landmarks when it comes to spatial learning (Löwen et al., 2019, p. 13) and (Ben-Elia, 2021, p. 9). Relating to the topic of spatial learning, it is also useful to think of design and placement of landmarks, as it is possible to design geographic information displays that it increases the spatial learning process. Exactly that was studied by Thrash et al. (2019), in the sense that specific design recommendations emerged from this paper. Seven recommendations of design for landmarks, routes and topology emerged (Thrash et al., 2019, p. 6). The three recommendations for landmark were stated as followed.

- "Emphasise emotionally relevant landmarks" (Thrash et al., 2019, p. 6).
- "Provide virtual landmarks via augmented reality" (Thrash et al., 2019, p. 6).
- "Emphasise landmarks at critical decision points" (Thrash et al., 2019, p. 6).

Those recommendations show that the design plays a crucial role and that in general the inclusion of such landmarks can be beneficial for the spatial learning process (Li, 2020, p. 432). Having now mentioned the design aspect of such displayed landmarks, a more in-depth discussion of specific design issues will be explored in the next section.

## 2.5 Design Aspects on Inclusion of Landmarks

As described above, landmarks can form an useful help in navigating through an environment and help increase the spatial learning process (Löwen et al., 2019, p. 11-13). There is also growing scientific work regarding such navigation design ideas for indoor buildings, which shows, how broad this topic is and that it is used in different research areas (Gotlib, 2019, p. 164). Nevertheless, in this thesis the focus lies on outdoor navigation and the symbolising of outdoor landmarks. A crucial aspect which has to be looked at more deeply though, are the design aspects of such landmarks, which opens a field of various studies and research. In the following subsections certain aspects and a part of this research will be elaborated.

### 2.5.1 Symbolisation in Navigation

The study on how to design such symbolisations in map interfaces is a complex task. Basically, it is crucial that the user of such an interface with for example symbolised landmarks can use the landmarks with the least effort, but highly profits from its display (Elias and Paelke, 2008, p. 3). As a result, the design of such landmarks should be based on how people can best recognise and use such symbolisations (Elias and Paelke, 2008, p. 3, 4). Also factors on how many objects and how much information are visualised influences the user's perception and therefore have a huge influence on the map design (Westerbeek and Maes, 2013, p. 302). Important is not only the display of the landmarks but also the rest of the maps, for example if the base map is shown as a real-world aerial picture or a generalised map. A study by Dillemuth (2005) has looked at that a bit more closely. It has been found that for the user the latter would be more effective in navigation, although the map is more detailed and represents the reality more accurately (Dillemuth, 2005, p. 298). A reason for that could be the question of information load on a map display. This is a crucial issue which has to be addressed. In other words, an example would be selecting specific points, which are shown on maps, that could be landmarks and not displaying information that is not needed to avoid information overload (Dietze and Böhm, 2005, p. 214). When talking about small screens, for example mobiles or tablets this issue is even more important as the screen size and therefore the visualisation medium is smaller (Setlur et al., 2010, p. 1). So the contrast between the objects, for example a landmark and its base map has to be big enough to ensure faster search time and an overall better orientation on the map (Setlur et al., 2010, p. 2). It is also crucial that the displayed map with its features is designed in the way that it supports the mental and cognitive tasks of the user. This can be done through changes of the map context (Crease and Reichenbacher, 2011, p. 14). Such generalisation processes to ensure better readability of the map can be done differently. For example processes like selection, simplification, aggregation, typification or displacement of features are different ideas (Edwardes et al., 2005, p. 22-26). Those processes can be applied individually or combined and should guarantee that if lots of data is visualised, the content can be reduced to the essential and thus better visualised (Edwardes et al., 2005, p. 22-26). Already in the year 1997 a study by Devlin and Bernstein looked at map variables and their representation, and it was mentioned that care should be taken with the amount of colour and information on a map and how this influences the performance (Devlin and Bernstein, 1997, p. 107). In addition to that when working with modern devices it is also possible to pan and zoom in

the map. This enables fast orientation for the user and different information can be symbolised depending on the zoom level (Setlur et al., 2010, p. 3, 4). Setlur et al. (2010) mentioned also the selection tool of points of interest, where more specific information can be displayed when clicking on such a point of interest (Setlur et al., 2010, p. 3, 4).
After having a closer look on the influence of landmarks regarding the spatial learning process, it is important to deepen the knowledge a bit on how landmarks are being symbolised in navigation applications.

### 2.5.2 Implementation of Landmarks into Navigation Applications

When it comes to inserting landmark symbols into a map, several questions arise. Back in the 20th century Jacques Bertin defined some guidelines for designing. An example of illustrated information was the symbolisation or colourisation of map elements and also how those are illustrated in a map. Points as readability and how a map can be understood the best are being investigated and discussed (Bertin and Berg, 1984, p. 1-411). Limitations of a map, when too many symbols or information are illustrated have been looked at closely and specifically for instance when different symbols are illustrated onto a map (Bertin and Berg, 1984, p. 156-157). So a map can only show a number of variables and overload of the map should be prevented (Bertin and Berg, 1984, p. 154-159). Another crucial question is about the degree of abstraction of the inserted symbolisation or image. In other words, should the landmark that is to be inserted into the map be an abstract symbol or a real image or real symbol (Zhu et al., 2022, p. 674)? There is a tendency that different landmark visualisation styles have different effects on how those landmarks get recognised and how those can affect spatial knowledge (Kapaj et al., 2021, p. 6). As already stated above, it is important that the user perspective is being considered when searching about the effective visualisation for landmarks (Elias and Paelke, 2008, p. 3). For the optimal choosing of a landmark visualisation some steps have been presented by Elias and Paelke (2008).

- Point 1: The visualised landmark should be similar to the one in the reality so that the user can recognise the landmark as fast as possible (Elias and Paelke, 2008, p. 3).
- Point 2: Specific parameters should be looked at closely, as for example the user, conditions and environment and the hardware used (Elias and Paelke, 2008, p. 3).
- Point 3: This points includes the development of specific design ideas on how to illustrate landmarks (Elias and Paelke, 2008, p. 3).
- Point 4: After the development, the design ideas should be critically looked at (Elias and Paelke, 2008, p. 3).
- Point 5: The last point then is stating that the most fitting idea should then be included (Elias and Paelke, 2008, p. 3).

Regarding the question of using an abstract symbol or rather a real-world picture, the process of abstraction has to be looked at a bit more closely. Basically it can be stated that there are different levels of abstraction, ranging from a real-world picture to a simple abstracted symbol or even just a word (Elias and Paelke, 2008, p. 12). This continuous transition from real to abstract is illustrated in the Figure 6 by Elias and Paelke (2008).

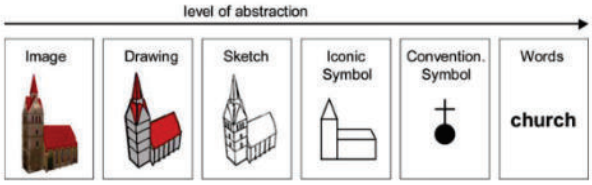



Figure 6: Different degrees of abstraction (Elias and Paelke, 2008, p. 12)

On the left side of Figure 6, a real-world picture of the landmark can be seen, on the right side on the other hand is an abstract symbol and also a word, which illustrates the landmark. Those levels of symbols have different advantages and disadvantages, as for example a pictorial symbol. The second to the right, has the advantage that this kind of pictorial symbol is recognised by the user rather easily and with less effort, but is not as detailed as the image on the far left (Elias and Paelke, 2008, p. 10) and (Xiao et al., 2020, p. 11). A study by Lee et al. (2001) examined the use of real-world pictures for the symbolisation of landmarks (Lee et al., 2001, p. 87). In this study where navigation and landmarks, specifically also their symbolisation, have been looked at more closely, the landmarks were included as two-dimensional real-world pictures into the map at the location, where the landmark is located. The map used is a perspective map view, in other words the birds-eye map gets transformed so that the map and the perspective seems more realistic and closer to reality for the map user (Lee et al., 2001, p. 90). Another study by Wunderlich and Gramann (2021) looked at pedestrian navigation also using real world visuals. In this study not visualised in a map but rather in real life navigation (Wunderlich and Gramann, 2021, p. 1-14). The real-world visuals of landmarks showed a helping effect in navigation (Wunderlich and Gramann, 2021, p. 14). Going then further in the direction of abstract symbols, different studies have abstracted landmarks to visualise them. A recent published work by Zhu et al. (2022) investigated the effect of landmarks, visualised as on the one hand, like the other studies, as real-world pictures, but then also as pictograms, icons and texts on the other hand (Zhu et al., 2022, p. 674). Another study by Döllner and Buchholz (2005) visualised specific buildings, which function as landmarks as abstracted but quite detailed three-dimensional objects. Such visualisations can rather be detailed or not, depending on the degree of reality which is needed. So specific characteristics of a building can be provided (Döllner and Buchholz, 2005, p. 174, 180).

Independent of the abstraction grade, an important point to mention regarding two- and three-dimensional objects is, that it can be, that three dimensional visualisations can be quite overwhelming for a user, thus resulting in less knowledge acquisition in comparison with two dimensional and also complex in generating (Liao et al., 2017, p. 481-490). For the creation of three-dimensional objects or also the embedding in a three-dimensional environment, specific software is needed, which can be lavish for large scale maps, but the advantage is, by using such specific software it can be designed and illustrated with a high degree of detail (Döllner and Buchholz, 2005, p. 173).

Coming to the detailed design of such visualisations, it is again complex to devise the best suitable picture or symbol. Aspects as size and colour of the symbols and pictures have to be taken into account, so for that it is not too big in the map and does not cover other objects or other information in the map. Therefore, abstraction of detail is a possible way to simplify the symbol and to make it smaller (Elias and Paelke, 2008, p. 12). Regarding the colour of such images and symbols, different studies have developed various ideas. The pictures for example, take the colours they also have in the real world as well (Elias and Paelke, 2008, p. 12). Xiao et al. (2020) for instance emphasised that the colour of symbols would be good chosen if the colour is brighter than the base map to have clear visibility of those features (Xiao et al.,

2020, p. 11). In this study the symbols have been differently coloured according to their type (e.g. food or shopping) (Xiao et al., 2020, p. 11). Another study by Zhu et al. (2022), used one single colour in a bright blue hue to visualise the symbols, regardless on the type of the feature (Zhu et al., 2022, p. 674, 675). The decision on which visual variable to use to symbolise something is not clearly defined, but there is evidence that there are differences in readability and effectiveness between the size of the symbols and the choice of colour or hue and the orientation (Garlandini and Fabrikant, 2009, p. 195-211). For example, the size of the symbols was found to be very effective in one experiment, the orientation of the symbols less (Garlandini and Fabrikant, 2009, p. 208-209). So the design is not as easy as thought and it can be seen, that there is a range of possibilities on how to design those features (f.e. landmarks) but the key concept still remains the same, that they should be presented in the most useful and efficient way for the user (Elias and Paelke, 2008, p. 3).

## 2.6 Inclusion into the Thesis

It could have been illustrated in the above subsections that navigation, wayfinding and routing are part of peoples everyday life and that those processes form a crucial aspect in different areas of the life (Ahmadpoor and Shahab, 2019, p. 1) and (Montello and Sas, 2006, p. 1). Important to state as well is, that navigation demands also cognitive skills (Haig, 2019, p. 14). Looking at the specific mode of transport of cycling, navigation is also a crucial aspect and having a growing form of transport with the bicycle this navigation aspect is essential to be looked at (Savino et al., 2021, p. 5). The inclusion of landmarks into this navigation question to improve navigational skills and spatial learning, was looked at more closely in the sections above and it was shown that both the definition of landmarks and also its effect on spatial learning is not fully cleared respectively is a complicated process (Yesiltepe et al., 2021, p. 405-407) and (Thrash et al., 2019, p. 6). Last but not least, the symbolisation of such landmarks into navigational applications raises many questions, but it is crucial that the user perspective, in more detail, that the user can profit maximally from it (Elias and Paelke, 2008, p. 3).

It is for the previous mentioned reasons, that in this thesis a study should be conducted to focus on this specific research area, namely the a priori spatial learning process in bicycle navigation with focus on the display of local landmarks. How the display of landmarks could contribute to the spatial learning process and if the different symbolisations differ. Study in this area is an actual topic and interesting to investigate and would be nice, whether a contribution could be made. So, generally spoken this is done, because this research area has not yet been studied very closely and therefore this paper tries to fill the knowledge gap of the influence of the a priori spatial learning process in bicycle navigation with the aid of landmarks.

# 3 Method

As a crucial part of this thesis, an empirical study was conducted from the 17th of January 2022 until the 14th of February 2022 at the Department of Geography in the University of Zurich, with the aim of answering the above stated research questions. Most participants took part in the study in January, but because many people were in home-office due to the ongoing Corona-Virus crisis or were ill during the possible study times, the experiment slots had to be extended until mid-February to have enough attendees. The study was conducted in English or German, depending on the participants preference. Due to the fact, that the study was bilingual, more people could be asked to participate. The methodology and the detailed procedure of the study are explained in more detail in this chapter.

## 3.1 Acquiring of the Participants

As mentioned above, the actual execution of the study started in the middle of January 2022 and lasted until the middle of February 2022. Therefore, the acquiring process for the attendees started right after the beginning of the new year. In order to recruit the number of participants, which was aimed for, people from the personal network and in addition individuals from the university network were asked to participate in the study. The potential attendees were addressed individually with a first information e-mail, where they could sign up for a Doodle to indicate which date and time slot they would like to participate (see e-mail in appendix chapter A). In addition to the determination of the date and time, the inclusion and exclusion criteria for the study participation were listed. Those criteria are illustrated in the Table 1 below.

| **Inclusion criteria** | **Exclusion criteria** |
|---|---|
| Healthy and no COVID related illness symptoms | History of neurological conditions such as epilepsy or migraine |
| 18 to 65 years old | Good spatial knowledge of the city of Aarau |
| Ability to ride a bicycle | |
| Federal (BAG) COVID requirements (vaccinated or recovered (2G)) and facial mask | |

Table 1: Inclusion and exclusion criteria for the conducted study at the University of Zurich

After the first information e-mail and the registration of the participants, a second and more detailed e-mail was sent to those who signed-up in the mentioned Doodle (see e-mail in appendix in chapter A). With this e-mail, some more information about the location and meeting point was sent and the declaration of consent was attached so that the participants could read it in advance. The consent form was signed later on-site prior to the experiment, where the attendees had time to read and study the document again (see declaration of consent in appendix chapter B). In addition to that, a link was attached in this e-mail, which led the participants to a "spatial ability pre-test", which they had to complete before the experiment. More information regarding this "spatial ability pre-test" can be found in the chapter 3.5.

## 3.2 Sample

For the study a total of 39 people were recruited to participate. Out of those 39, a total of 21 participants are male (approximately 54 %) and 18 (approximately 46 %) are female. The median of the age of all 39 attendees was 26 and the mean of the age of all 39 participants was 28.3. Another important aspect to mention is that 28 of all 39 participants (approximately 72 %) either are studying geography at the moment or have studied geography in the past. Only 11 of all 39 participants (approximately 28 %) have no study connection to geography. The reason for that is that a lot of people who attended in the study come from the university network and therefore had a connection to the field of geography. This is an important aspect, which is also later mentioned as a topic in the discussion section. At the beginning of the study, the aim was to conduct the study with at least 30 participants. This number is comparable with similar studies. As a reference, two studies have been taken into consideration, which performed experiments in a very similar field and similar manner. In those two studies, one involved 33 and the other 38 attendees (Cheng et al., 2018b, p. 1) and (Wunderlich and Gramann, 2021, p. 3). Therefore, the number of 39 participants was over the pre-defined minimal number and although the recruitment phase was not always easy due to the ongoing Corona-Virus crisis and as a result individuals, who were in home-office or not able to attend, it is great that 39 participants performed in the study.

## 3.3 Pilot Experiment

To improve the procedure of the study, several pilot studies have been conducted. With those pilot studies the course of the study could be improved and ensured that the actual study conducted later would run smoothly. In addition, the selection of the route to be used in the actual study could be determined according to feedback from the participants who had gone through different routes in the pilot study. Those different possible routes can be seen in the chapter 3.6. A more detailed look was taken at which route is easier or less suitable than the other. Some more detailed information about that can be also found in the chapter 3.6. The pilot study was done before the Christmas break with three different people. After those three runs and discussions with the supervisor, some important adaptations have been made. Overall, after every pilot study run the adaptation became more and more detailed and so the study could be improved. Due to the fact that the people who participated in the pilot experiment already were able to see the maps and the video of the study, they could not participate in the actual study later, because they would then have an advantage.

Some detailed adaptations which resulted from the pilot experiment runs, were the choosing of the appropriate route and landmarks, the spatial learning time for the participants, the procedure details and instructions and more. How the experiment then actually looked and was performed is explained in the following sections.

## 3.4 Materials

In this subsection the focus will be on how the hardware and the software setting in detail looked and what was used to conduct the study.

### 3.4.1 Hardware Setting

As already stated above, the study was conducted at the Department of Geography in the University of Zurich. Therefore, a lot of the hardware and tools could be used, as the University of Zurich, more precisely

the subgroup of Geographic Information Science, offered the possibility to make use of this hardware. In addition to the hardware used by the Department of Geography, the bicycle ergometer for the study could be loan from the Institute of Physiology at the University of Zurich for the experimenting time. The initial idea was to perform the study in the outdoor environment. However, after some consultations with the supervisors it was then decided that the study could also be carried out well in the in-house laboratory. Therefore, the study could be conducted in a more controlled environment. If the study would have been performed outside, it could have been less controlled but more realistic. The balancing of these two options led to the choice of a mixture between a fully controlled and a fully realistic scenario, which will become apparent later in the paper. Thanks to my supervisor and the subgroup of Geographic Information Science, some documents which were later used for the study, could be used as guides.

The location chosen for the study was an indoor laboratory located at the University of Zurich. The setting of the room can be seen in the Figures 7 and 8, where there is on the one hand an animation which visualises the setting seen from the top of the room and on the other hand a picture how it looked like, when the participant performed in the study.

The setting of the room consists of different parts. As can be seen in the two pictures in Figure 7 and 8, the environment looks like a cave. The participant sits in the middle of three large wide walls with the front wall having a projector on which the video is displayed. On the other two walls on the left and right side there is no video or other information projected. The bicycle ergometer on which the attendee is sitting during the "performing phase" is programmed that there is no resistance, so that the participant does not have to exert any effort, but can simulate the bike riding process. The light is turned off so that the video can be watched clearly. The study conductor sits on a chair at a table behind the attendee to have an overview of the participant and the ongoing performance and also to be able to easily see and hear the participant's decisions. The reason that the study conductor does not sit in the eyesight of the participant is that there is no distraction possible between the study conductor and the participant.

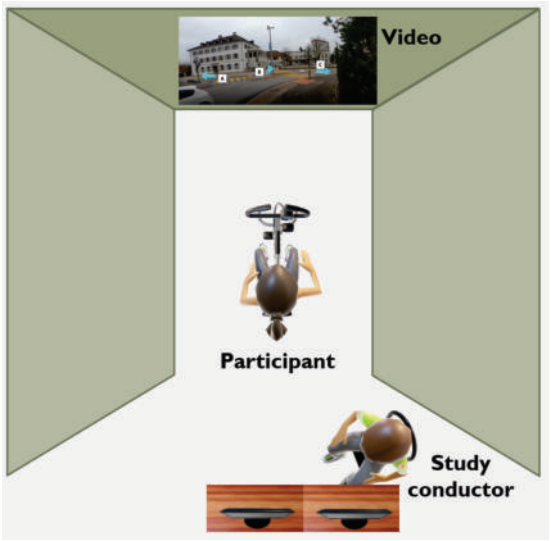



Figure 7: Hardware setting from birds view perspective

Figure 8: Hardware setting from the study conductor perspective

As the description of the Figure 8 suggests, you can see the participant sitting on the bicycle ergometer and watching the video playing on the front screen. Having it mentioned earlier, the video is only projected on the front screen and not on the two screens on the left and right.

### 3.4.2 Software Setting

The software used to create the maps was ArcGIS Pro and ArcGIS Online, for which the University of Zurich had access to. Different participants, who performed under different levels, also had different maps shown. All those different maps could be created differently as a Web Map Application in ArcGIS Online, which was really convenient. This way, every map could be created specifically for its purpose and no map was overloaded. The web map application had different characteristics. Basically, it was interactive, meaning that the participant could interact in the map, in more detail the attendee was able to pan and to zoom up to a specific pre-defined level. Through the zooming not more information was shown, but for example the displayed landmarks could be looked at better, but more information on that will be illustrated in a later part of this thesis. Panning could be done via the mouse and staying clicked on the map, and zooming via the small wheel on the mouse or via the plus and minus symbol in the top left of the map. The small house symbol on the top left enabled the participant to return to the route, if they would get lost.

#### Design of the Map

As can be seen in the Figure 10 further down in the thesis, the exact route was signalised with an orange colour. At the beginning of the route, a green flag represented the starting point and the black and white flag the ending point. The landmarks, both symbols and pictures, were shown in the colours they represent in the reality. The base map did not contain any names, only the streets, parks and water bodies could be seen, respectively their shape could be identified. The idea to only show the landmarks and the route, was because of map overload issues mentioned in the literature part. For orientation purposes a scale was shown and the map was oriented towards the north. The web application was constructed in such a way that the orientation of the map could not be changed. However, panning and zooming in the map was possible, as explained above. The map was limited at a certain small and big scale (between 1:100 and 1:15 000), to ensure practicability. Up to these scales, the route was visualised exactly on the roads and paths of the base map.

### Design of the Video

The video shown on the front screen was recorded via a GoPro camera mounted to the bike helmet to simulate the rider's perspective. The route was recorded without any stopping in between so that it is as realistically as possible. When stopping at a decision point, the video was paused and different arrows were displayed in the video for the possible directions. This can be seen in Figure 9 below. Important to state is that the video did not stop at every possible decision point and not at every decision point where there were landmarks. In other words, it stopped at some pre-defined decision points where there were landmarks and where there were no landmarks. More details will be illustrated in the procedure part later. The stopping frames of all the asked decisions in the video can be seen in the appendix under chapter E. In total the video lasted approximately 14 minutes, representing a route of around 2.5 kilometres. Observations during the experiment showed that the video reflected the ride in reality quite well, as it could be observed, for example, that the participants tried to avoid certain things on the road or also performed the movements on the bicycle ergometer, such as accelerating or braking, as if they were on the road in reality.

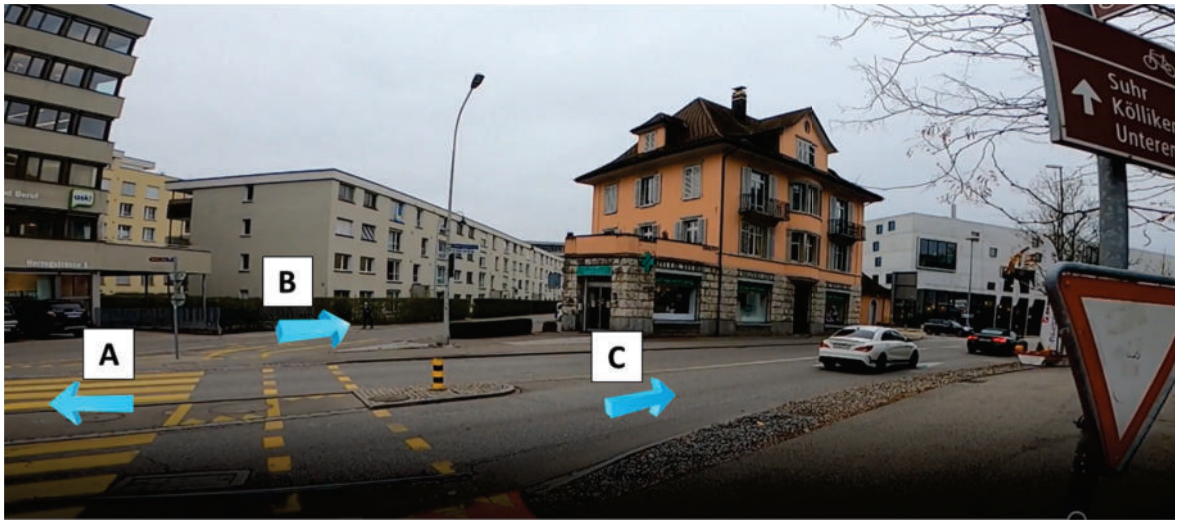



Figure 9: One of many stopping situations in the video (recorded with GoPro camera)

## 3.5 Spatial Ability Pre-Test

As the different participants have varying knowledge and abilities to orient themselves and perform spatial and navigational tasks differently, a pre-test on spatial ability should therefore provide an assessment of how well attendees perform a spatial task. Important to mention is that the task of the study requires the participants to read a map from bird perspective and later orientate themselves the same as in reality, so the test has to cover that ability. After some consultation, two possible tests have been taken into consideration. The first is called "Mental Rotation Disk" and the second is called "Santa Barbara Sense of Direction" (Peters et al., 1995, p. 39-58) (Hegarty et al., 2002, p. 445, 446). It was decided that the latter was more appropriate to the study conducted here, respectively that this test better covered the tasks of the study and better matched the required tasks of the study. The test was transferred to a Google forms survey, to allow the participants to do the test at home with access via a link.

### 3.5.1 Santa Barbara Sense of Direction

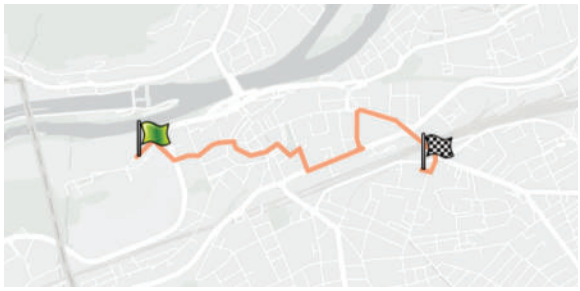
The test consists of 15 questions, where the participant can choose for all the questions on a scale between values from one to seven, where one represents "strongly agree" and seven "strongly disagree" (Hegarty et al., 2002, p. 445, 446). Generally spoken it can be said that the test can show how the environmental abilities of the participants are and that there is a potential correlation between the test result and the sense of direction of people, or also in other words spatial orientation ability (Hegarty et al., 2002, p. 443) and (Boccia et al., 2016, p. 2799). It was therefore thought that the test could suit in the planned experiment. In addition to the official questions from the test, three questions about the name, age and gender have been put in front of the test. The test results will be illustrated and explained in the chapter four. Based on the score the participants achieved in this test, they were distributed evenly on all the three different levels to ensure, that under every level similar attendees (in term of the SBSOD score) participated. Similar approaches have been done in another study, where based on the score, the participants have been split up (Janzen et al., 2008, p. 41).

## 3.6 Details of the Route and Landmarks

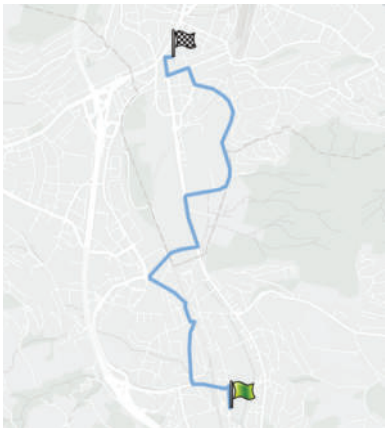
As a key element for this study was the navigation with the bicycle on a specific route where landmarks are visualised, the selection of both, the route and landmarks, will be explained in the following.

### 3.6.1 Route Selection

The choosing of the appropriate route for the main study was done as followed. As already shown in the paragraphs above, the route in Aarau was chosen, but here briefly the process to this decision is outlined. As the study is carried out in the laboratory at the University of Zurich in Switzerland and a lot of the participants either study or work at this University or in the area of Zurich, it was decided to not select a route in the city or canton of Zurich. Due to the fact that some personal urban knowledge about Aarau and Lucerne was present, and the fact that many local landmarks are present in both cities, it was decided to select the route in one of the two cities. Both cities are located in Switzerland as Aarau is the capital of the canton of Aargau and Lucerne is the capital of the canton of Lucerne. A variant analysis was carried out for the optimal route selection. At the beginning, a possible route evaluation was done via Google Maps and after that physically in the real world. So, the routes could be looked at in more detail and changes of the route and the junctions could be adapted and changed. Two possible routes were chosen for both Aarau and Lucerne, so in total four routes, where different factors have been taken into account. The route had to be driven with the bicycle and should last between 10 and 20 minutes. In addition, various landmarks had to be located along the route, more specifically at certain (crucial) decision points. After having those two routes for both Aarau and Lucerne, one route each was removed of the variant analysis due to the position of the landmarks and other disruptive elements on the route. Therefore, only one possible route in Aarau and one possible route in Lucerne remained. Those two routes are now explained in a bit more detail below.



(a) Most appropriate route variant of Aarau



(b) Most appropriate route variant of Lucern

Figure 10: Two last route variants from Aarau and Lucerne

The route in Aarau is starting at the western part of the city, going through the city centre with the old town, then navigating next to the train station to then end in a neighbourhood in the eastern part of the city. The route in Lucerne is starting in the municipality of Horw, which is south of Lucerne, then navigating through a suburb of Horw, until reaching an industrial part of Lucerne, which then is leading into a residential area in Lucerne. Along these two routes, various landmarks were located at decision points, which will be illustrated in the next subsection.

### 3.6.2 Landmark Selection

As already mentioned, the route was selected in a way, that specific landmarks were located along the route. Only local landmarks were chosen, as the entire study is investigating only local and not global landmarks. The definition of Steck and Mallot (2000) was used here to choose the landmarks, as local landmarks represent landmarks which can solely be seen from a small distance (Steck and Mallot, 2000, p. 69). The selection of those landmarks was therefore done by hand, which worked for the scope of this experiment but would be quite lavish when this selection would be done for greater areas. An approach, which was not used here but is worth mentioning is the selection of landmarks through a neural network (Zhu and Karimi, 2015, p. 260). Alternatively, a survey could have been conducted to determine which landmarks people find most appropriate. Another study by Dubey et al. (2019) came up with a method to identify possible landmarks, among others through the use of eye-tracking (Dubey et al., 2019, p. 10). Regarding the number of the landmarks, the pre-results of a study by Cheng et al. stated, that the best performance is achieved with five landmarks (Cheng et al., 2018a, p. 1). As the route in the conducted study is rather long, the number of displayed landmarks was increased to seven. Generally, it was considered that the landmarks were evenly distributed over the route. In addition to that the landmarks had to be located at a decision point in the route. The categorisation and choosing of the landmarks was done similar to the definition of "Decision points" and "Potential decision points" in the literature (Keil et al., 2020, p. 3). In other words, there is a possibility that at this specific point the route direction is changing, but does not necessarily have to. A study by Keil et al. defined these points as either decision points or potential decision points (Keil et al., 2020, p. 3). In addition to the location of the landmarks at decision points or potential decision points, two important criteria which were mentioned above in the literature review, were considered when deciding

which landmarks are being taken on the route. Those two important aspects were visibility and saliency. In other words, the landmarks must be good visible and also visually salient. Those two criteria were already mentioned in the literature part and can be understood as two important criteria in defining a landmark (Yesiltepe et al., 2019, p. 1-4)(Yesiltepe et al., 2021, p. 404). It is important to state here, that not at every decision point there was a landmark visualised as this would have simply been to many landmarks. However, more information regarding this is given in the results section. Landmarks on both routes (Aarau and Lucerne) were chosen based on these criteria. There would have also been a possibility to take not a single object as a building or a bus station as a landmark, but rather a road, a tunnel or train tracks, which represent longer features, but it was decided to only take single objects.

In the Tables 2 and 3, only the landmarks of the two routes of Aarau and Lucerne, which were chosen the best route for each city, are listed. The following landmarks were selected for the last two routes which were most suitable, one in Aarau and one in Lucerne. As stated above, the selection was based on the criteria in the literature part. The decision as to which landmark to take was made by myself. Alternatively, a survey could have been conducted with other participants at the beginning to decide which landmarks would fit best.

| Landmark description | Route allocation | Symbolic visualisation | Picture visualisation |
|---|---|---|---|
| **Landmark 1:** White building which has a short tunnel under it where pedestrians and bicycles can go through (Decision 3). | **Aarau** |  |  |
| **Landmark 2:** Fountain standing on the right side of the route (Decision 4). | **Aarau** |  |  |
| **Landmark 3:** Special looking, rosa building with no windows located at a central position (Decision 5). | **Aarau** |  |  |
| **Landmark 4:** Big, blue bus station building on the right side of the route (Decision 8). | **Aarau** |  |  |
| **Landmark 5:** White, old building in the front of a intersection (Decision 9). | **Aarau** |  |  |
| **Landmark 6:** Tall, red building on the right side of the route (Decision 10). | **Aarau** |  |  |
| **Landmark 7:** Orange building on the right side of the route (Decision 11). | **Aarau** |  |  |

Table 2: Overview about the chosen landmarks on the route Aarau (both symbols and pictures). Symbols for landmarks 1-7 based on symbols from OpenStreetMap (OpenStreetMap, 2022).

| Landmarkdescription | Route allocation | Symbolic visualisation | Picture visualisation |
|---|---|---|---|
| **Landmark 1:** Green building on the right side of the road (Decision 2). | **Lucerne** |  |  |
| **Landmark 2:** Red, modern building on the right side of the road (Decision 4). | **Lucerne** |  |  |
| **Landmark 3:** Roundabout with vegetation structures on it (Decision 6). | **Lucerne** |  |  |
| **Landmark 4:** Golden, special sport building on the left side of the road (Decision 7). | **Lucerne** |  |  |
| **Landmark 5:** Small bus station building on the left side of the road (Decision 8). | **Lucerne** |  |  |
| **Landmark 6:** Dark, rosa residential building on the left side of the road (Decision 9). | **Lucerne** |  |  |
| **Landmark 7:** Grey, modern building on the right side of the road (Decision 11). | **Lucerne** |  |  |

Table 3: Overview about the chosen landmarks on the route Lucerne (both symbols and pictures). Symbols for landmarks 1-7 based on symbols from OpenStreetMap (OpenStreetMap, 2022).

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### 3.6.3 Landmark Display

The displaying of the landmarks mentioned above is in need of some short explanation here. For both the symbols and the pictures, it was decided to include the landmarks as they look from the front. In other words, how the landmarks look like in the video when the participant is watching the video. They are not symbolised as three-dimensional objects and thus can only be seen from the front. In a virtual environment, also the inclusion of three-dimensional objects would be possible, which was not used in this study. An example was a study which dealt with landmarks, but on a smaller scale, regarding in building navigation, where landmarks were displayed as three-dimensional objects (Parush and Berman, 2004, p. 380, 381). Another study at the University of Zurich also included the landmarks in a virtual environment three dimensionally (Cheng et al., 2018a, p. 1). Due to the fact that the study in this master thesis was not done in a virtual environment, the landmarks were displayed here two-dimensionally. Additionally, it was decided to directly include those into the map and not as a pop-up marker, where they only appear when clicked on them. Such an implementation in an experiment was done by Löwen et al. (2019). In this study, landmarks were illustrated with a pop-up marker to symbolise the landmark (Löwen et al., 2019, p. 5). The size of the displayed landmarks was chosen, that they were clearly visible and not too big or too small between the scales of 1:100 and 1:15 000. Unfortunately, the size of the landmarks could not be adjusted depending on the zoom level, that is why a size was chosen which suited for all those zooming levels. The landmarks have been visualised depending on the group level categorisation, which will be explained in more detail later.

#### Landmark Symbols in the Map

As stated in the Tables 2 and 3, the shown and chosen symbols are from the design of the OpenStreetMap map, respectively the basic shape and form is taken from there, but then modified, based on the colour and form of the landmark independently of OpenStreetMap (OpenStreetMap, 2022). Due to the fact that it is necessary to visualise the landmarks as symbols, an appropriate symbol palette had to be chosen. All symbols have the same size, resolution and same level of abstraction to ensure comparability (Elias and Paelke, 2008, p. 12). Symbols of the building are coloured in the main building colour. This was done with the colour picker on the real world-picture, which was sometimes difficult because of the different light settings. Some symbols (bus station, fountain and turn around) are symbolised with black and white, but tried to make it as similar as the building in regards of the abstraction level. Another important point is that the house symbols show the appearance of the landmarks and the other symbols, in more detail the bus station, the fountain and the turn around show the function of the landmark.

#### Landmark Pictures in the Map

The landmarks visualised as pictures found real-world pictures in the map. To ensure comparability between the different pictures of the landmarks, several criteria had to be looked at. All pictures had to have the same size and also approximately the same resolution. In addition to that, all of the pictures had to be taken from the front view which the participant sees in the video. Also, the lighting for every picture had to be similar so that the colours are comparable.

#### Without landmarks in the Map

In the without situation, which is meant to symbolise a kind of baseline, the condition is represented in which no potential landmarks are visualised. Therefore, the participants performing in this group did not

have any landmarks visualised. Only the route itself was visualised for the participants in this group.

## 3.7 Study Design

### 3.7.1 Dependent and Independent Variables

In the outlined quantitative and partially qualitative study, there are dependent and independent variables. Generally speaking, it can be stated that the dependent variable gets influenced by one or more independent variables (Martin, 2008, p. 25, 26). In the study the dependent and independent variables are defined as followed. For the **first hypothesis**, which states that spatial learning can be improved if local landmarks are displayed in addition to the exact planned route, resulting in fewer direction change errors at decision points, the independent variable is the display of local landmarks on a map. The dependent variable on the other hand, is the performance of the spatial learning process, influenced by the displayed landmarks, in other words the number of correct or incorrect turns. For the **second hypothesis** which states that representing the local landmarks as pictures instead of symbols increases spatial learning of the planned route, the independent variable is the representation form of the local landmarks, which leads to better memorisation of the route and fewer errors at decision points for direction changes. The dependent variable on the other hand, is the performance of the spatial learning process influenced by the displayed landmarks, in other words, the number of correct or incorrect turns.

### 3.7.2 Variables and Control Variables

Different control variables had to be taken into account before and during the conducted experiment. Those are variables which should not vary between the participants and therefore have to be controlled (Martin, 2008, p. 27). Here are some of those control variables listed. Some of those have already been explained above, but as an overview are listed here again.

- Spatial learning advantages and disadvantages of participants.

Through the spatial ability pre-test this could be balanced up to a certain degree. It means that different individuals tend to have better or worse spatial orientation and navigation abilities than other people.

- Age and gender of the participants, geographical knowledge and bicycle experience.

Another essential points which had to be considered are the age and gender of the participants. Those parameters were monitored and in the case of gender, care was taken to distribute evenly among the groups, besides the spatial ability pre-test parameter. The result was that 7 male and 6 female participated at each level. Additionally the geographical knowledge was controlled in the way that participants were excluded from the studied if they had spatial knowledge of the city of Aarau.

- Characteristics (temperature, light etc.) of the room where the study is conducted.

The room characteristics and the procedure of the experiment had to be carried out uniformly and as equally as possible as explained above. This is important, because the results can only be compared if the participants had the same experiment conditions (Martin, 2008, p. 27).

### 3.7.3 Study Participants Design

An important point which was considered in the experiment was the question whether a "between-subject" or a "within-subject" design should be chosen for the study. The former means that one participant only performs under one condition, in this case being only assigned to either the "Without", the "Symbols" or the "Pictures" group. The latter on the other hand, would mean that a participant would perform under all conditions (Martin, 2008, p. 148). Both methods have their advantages and disadvantages, but in this master thesis it was decided to use a "between-subject" design. The main factor therefore was the reason that if a participant would perform under more than one condition, different routes would have been needed to be comparable, because otherwise the participant would know too much about the map and route already (Martin, 2008, p. 155). However, the main disadvantage is that more participants need to be recruited when using a "between-subject" design instead of a "within-subject" design (Martin, 2008, p. 169).

### 3.7.4 Study Procedure

The correct procedure of the experiment is a key aspect, so that the returning results can be used and evaluated correctly. Care had to be taken to ensure that a uniform conduct of the experiment was implemented, as for this every participant had the same conditions. This uniformity is particularly important when considering the term of "demand characteristics". This term refers to certain subtle cues that the participant in the study may receive from the person guiding the study through his or her behaviour or speech (Orne, 1962, p. 783). To counter or minimise this effect, the information was read aloud and instructed via pre-defined text, so that the same kind of words were told at the same time of the experiment to all participants similarly (Martin, 2008, p. 75). These documents can be found in the appendix under chapter C.

After the more detailed explanations of the study design, as for example the hardware setting and software setting, presented above, the study procedure will be illustrated in the following paragraph. The study was divided into three phases called the "learning phase", the "performing phase" and the "questionnaire phase", where the "learning phase" was chronologically before the "performing phase" and the "questionnaire phase" was in the end. The planned time for every step is illustrated in Figure 11 below.


Figure 11: Procedure of the main study with the approximate time for every step

In the "learning phase" the participant sat down in front of a computer and was asked to remember a specific route from a start point to an end point. Depending on the group they were associated with, they had different information displayed in the map. There were three different groups which differ from each other in what is displayed on the map. The map in this phase was shown on a computer through a pre-installed web application. Participants had a time constraint of two minutes to remember the route and the turnings to take. This number was set as part of the pilot experiment, which sought to find an appropriate time to match the real-world experience. During the pilot studies, times between one and five minutes had been tested and it was decided to use two minutes. In addition to the pilot experiment it was found in

the literature that another study with a similar topic used three minutes to show the participants a map (Deakin, 1996, p. 27). So, this value was also taken as a reference. The three groups will be explained here shortly and how those maps looked like in the web application.

| | |
|---|---|
| **Group 1:** Map without any additional information **("Without" group)** | In this group the map for the participant only shows the exact route but with no additional information on it. Streets and other buildings are not named on the map. This group represents the baseline, as here is no landmark information visualised. |
| **Group 2:** Map with additional landmarks as symbols **("Symbols" group)** | In this group the map for the participant shows the exact route and 7 landmarks located at decision points and displayed as simple symbols. Streets and other buildings are not named on the map. |
| **Group 3:** Map with additional landmarks as pictures **("Pictures" group)** | In this group the map for the participant shows the exact route and 7 landmarks located at decision points and displayed as real-world pictures. Streets and other buildings are not named on the map. |

Table 4: Three different experiment groups ("Without", "Symbols", "Pictures")

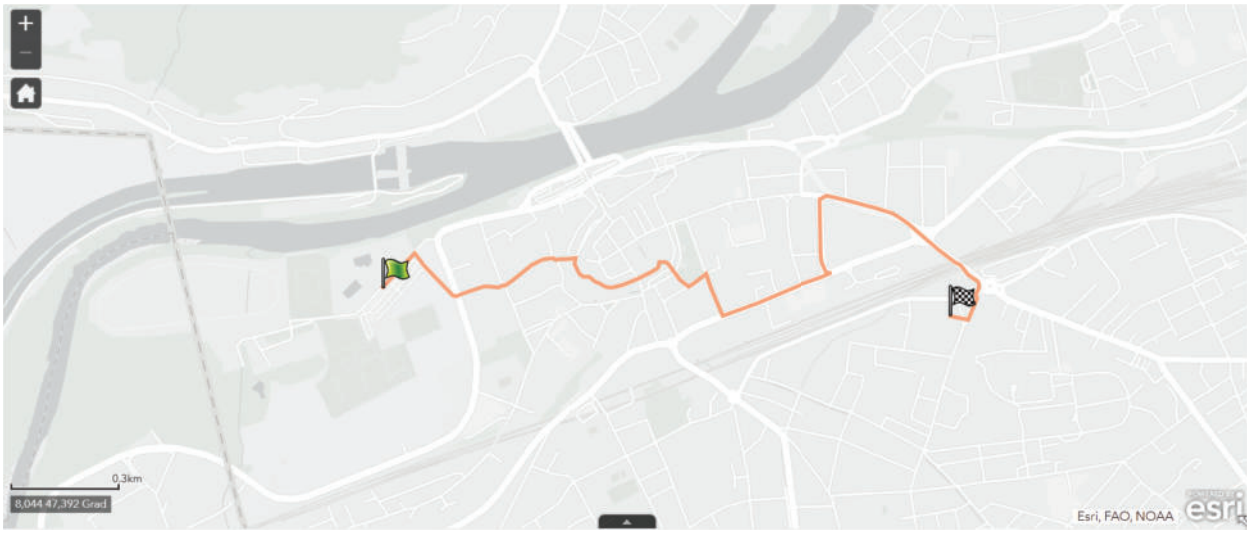



Figure 12: Map for participants in "Without" group

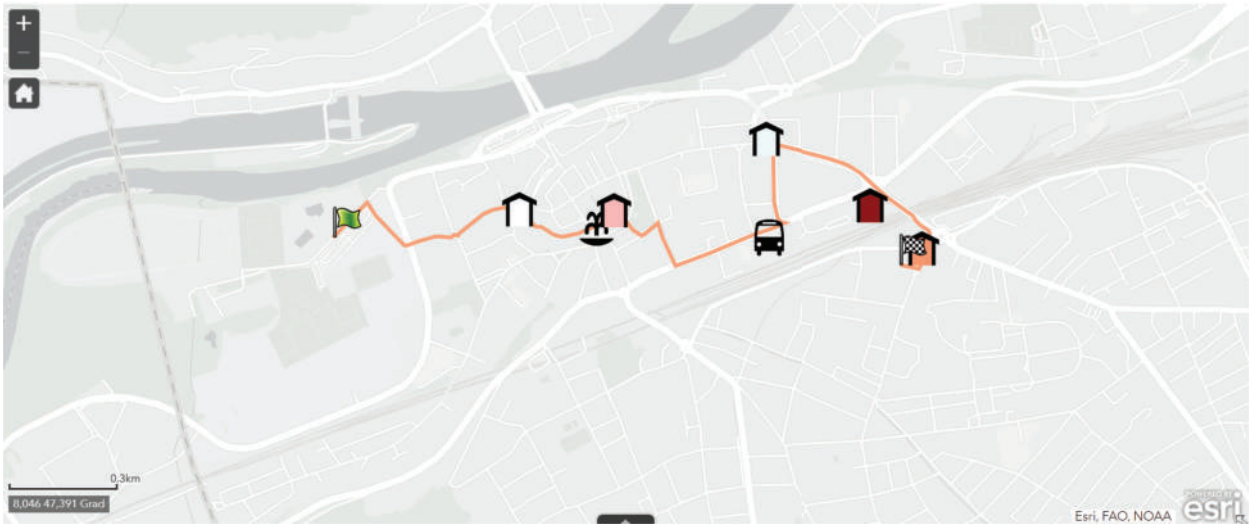



Figure 13: Map for participants in "Symbols" group


Figure 14: Map for participants in "Pictures" group

The participants then had as explained above two minutes time to "learn" the route, meaning that they should remember all the turnings to take. After those two minutes, the study changed in the "performing phase", where the map which has been shown before, was closed and no additional help was given to the participants anymore.

In the "performing phase" then the participant changed place and sat on a bicycle ergometer in front of a big screen and "drove" the route. Driving in this case meant, that a video was played with the same route as on the computer recorded with a GoPro camera on the helmet. The video then stopped at certain decision points where the participant was asked to indicate the direction where the route continuous. So, the decision can be either correct or incorrect for every decision. In addition to the direction, the participant told the study conductor how confident the decision was using three possibilities (unsure, neutral, sure). So the performance which was measured was the amount of correct decisions taken in comparison with all

decisions, respectively with the decisions which wanted to be looked at. The way of communication between the study conductor and the participant was verbally, meaning that when the video stops at certain decision points, there are different arrows with different letters shown and the participant was instructed to tell the letter and as mentioned before, how confident the decision is. In addition to this and without the knowledge of the participant, the decision time was stopped. This decision time is the period between when the video is paused and when the study conductor is informed of the direction (in form of the letter). Important to note, is that the participants did not have a time restriction, but to ensure that some of them did not think too long about a decision, the study conductor reminded the participants after 30 seconds that they should decide in the next seconds. The reason for that is to simulate the real world, where people often also do not have time to wait that long at an intersection and aim to continue their journey right away.

After the "performing phase", there was the "questionnaire phase" where the participant changed place again in front of the computer and was asked to fill in a questionnaire about the two previous phases. In the questionnaire, the participant was asked to fill in specific questions about the task they had done or about the maps and its component. Therefore, the participants had no specific time restriction.

From this description, it is clear, that the experiment was a multilevel experiment (three mentioned conditions/levels), of the independent variable (Martin, 2008, p. 176). In the end, the collected data are both quantitative and qualitative. So, in the case of the quantitative results the data are finally visible as numbers. Looking at the qualitative results, the data are not specifically numbers but for instance text information (Martin, 2008, p. 5). The data resulting from the procedure are shortly illustrated in Table 5.

| | |
|---|---|
| Decision data for every decision, where video is stopped. | Quantitative (true or false) |
| Confidence data for every decision, where video is stopped. | Quantitative (unsure, neutral sure) |
| Decision time data until for every decision, where video is stopped. | Quantitave data (time) |
| Questionnaire data | Quantitave data and qualitative data |

Table 5: Different data and its characteristic which was collected in the experiment

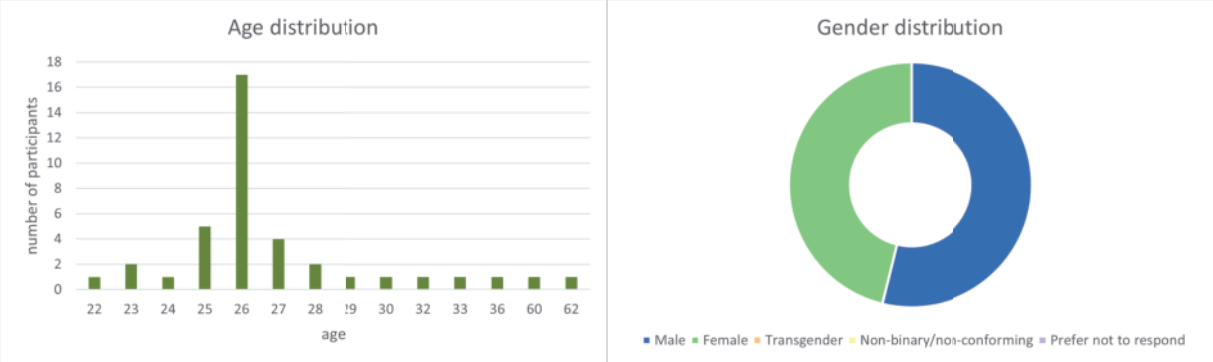
# 4 Results

Most of the analysis of the collected data was done with the software R Studio and additionally with Excel and Google Forms. Both descriptive statistics, in other words the presentation of the data and the basic parameter, and explorative statistics, in more detail the searching for systematic connections and correlations, have been done (Steland, 2007, p. 1). Therefore in this section of the thesis the results from the conducted study are shown and presented here in more detail and depth.

## 4.1 Results Spatial Ability Pre-Test

As already mentioned above a spatial ability pre-test was performed to rate the sense of direction of the participants (Hegarty et al., 2002, p. 441). Therefore the participants filled out the "Santa Barbara Sense of Direction" test which consists of 15 questions (Hegarty et al., 2002, p. 445, 446). For every single question the participant can choose between a number from one to seven, where for one they would strongly agree with the statement and for seven they would strongly disagree with the statement (Hegarty et al., 2002, p. 445, 446). For the scoring of the test, there is an official syntax which works as following. Firstly, the scoring of certain questions is reversed. Then the scoring of all the different questions is added and divided by the total number of questions. After that the resulting score represents the result of the test (Hegarty, 2022, p. 1).

Table 6 shows the answers of all 39 participants who filled in the spatial ability pre-test. Important to know is that some questions (2, 6, 8, 10, 11, 12, 13 and 15) are reversely scored. In addition to the official questions from the test, three questions about the name, age and gender of the attendees have been asked in the beginning of the test to gain demographic information. The results of these question are shown in the Figure 15 before then the answers of the spatial ability pre-test are illustrated.




(a) Age distribution of the participants

(b) Gender distribution of the participants

Figure 15: Age and gender statistics collected with the spatial ability pre-test

Regarding the age of the participants in the median over 70 % of the participants were between 25 and 28 years old. The youngest person who participated was 22 years old and the oldest person 62 years old. The gender distribution was that 21 participants identified themselves as a man and 18 participants identified themselves as a woman. No participants identified themselves as transgender, non-binary/non-conforming or preferred not to answer. Table 6 illustrates the results from the spatial ability pre-test, respectively the median of every answer. The displayed data and medians are before being reversely scored.

| **Question SBSOD (Hegarty et al., 2002, p. 445, 446)** | **Median [1 = not at all, 5 = very much]** |
|---|---|
| Question 1: I am very good at giving directions. | 3 |
| Question 2: I have a poor memory for where I left things. (reverse scored) | 5 |
| Question 3: I am very good at judging distances. | 3 |
| Question 4: My "sense of direction" is very good. | 3 |
| Question 5: I tend to think of my environment in terms of cardinal directions (N, S, E, W). | 6 |
| Question 6: I very easily get lost in a new city. (reverse scored) | 5 |
| Question 7: I enjoy reading maps. | 2 |
| Question 8: I have trouble understanding directions. (reverse scored) | 6 |
| Question 9: I am very good at reading maps. | 2 |
| Question 10: I don't remember routes very well while riding as a passenger in a car. (reverse scored) | 5 |
| Question 11: I don't enjoy giving directions. (reverse scored) | 5 |
| Question 12: It's not important to me to know where I am. (reverse scored) | 6 |
| Question 13: I usually let someone else do the navigational planning for long trips. (reverse scored) | 6 |
| Question 14: I can usually remember a new route after I have travelled it only once. | 3 |
| Question 15: I don't have a very good "mental map" of my environment. (reverse scored) | 6 |

Table 6: Results of spatial ability pre-test (SBSOD) (Hegarty et al., 2002, p. 445, 446) (median for every question)

## 4.2 Results Main Study

In this chapter the main results of the study are illustrated and explained in more detail. Based on the different data collected, various information and knowledge could be gained and analysed. Table 7 summarises the data which has been collected and briefly describes them. The different collected data is then shown in more detail in the results section on an ongoing basis.

| **Data Collection Type** | **Short Description** |
|---|---|
| Correlation of variables | Comparison between the results in the spatial ability pre-test and the actual performance in the main study. |
| Analysis of route decisions | Research if the participants performed different depending on their group association (”Without” group, ”Symbols” group, ”Pictures” group) - looked at over all decisions, decisions where there have been landmarks and decisions where there have been no landmarks. |
| Analysis of single decision points | Research if the participants performed different depending on their group association (”Without” group, ”Symbols” group, ”Pictures” group) for every single decision. |
| Decision and SBSOD score | Research if the participants performed different depending on their group association (”Without” group, ”Symbols” group, ”Pictures” group) and their score in the spatial ability pre-test - looked at over all decisions, decision where there have been landmarks and decisions where there have been no landmarks. |
| Analysis of confidence in decisions | Research if the participants performed different depending on their group association (”Without” group, ”Symbols” group, ”Pictures” group) regarding the collected confidence data of the participants. |
| Analysis of decision time | Research if the participants performed different depending on their group association (”Without” group, ”Symbols” group, ”Pictures” group) regarding the collected decision time data of the participants. |

Table 7: Short overview over all the collected data and what is being investigated in each case

To have a closer look at the data, every collection part in Table 7 is illustrated and explained a bit more in more detail in the following sections.

### 4.2.1 Correlation of Variables

As already explained in this thesis, the spatial ability pre-test was done to find out how good people rate their sense of direction (Hegarty et al., 2002, p. 441). As this is a self-assessment test it would be interesting to find out if there is a correlation between the result in this spatial ability pre-test and the performance in the study. The performance in the study is the number of correct decisions taken over incorrect decisions. Which then results in a number between zero and one, where the closer to one the better the performance.

This correlation was looked at over different groups. Firstly over all participants, secondly over participant in the "Without" group, thirdly over participants of the "Symbols" group and fourthly over participants of the "Pictures" group. The procedure for all the different groups was always the same, as first the data was tested on normality with the "Shapiro-Wilk" normality test (Bee Wah and Mohd Razali, 2011, p. 21-33). If the data then was normally distributed the "Pearson correlation coefficient" was calculated and if the data was not normally distributed the "Spearman correlation coefficient" was calculated (Steland, 2007, p. 180, 181). Important to state is that the following graphics show correlation analysis and not necessarily causation.

**Over all participants / Over all groups**

At the beginning the correlation of the performance was looked at over all groups, in other words for people associated in the "Without" group, the "Symbols" group and the "Pictures" group (Group 1, Group 2 and Group 3).

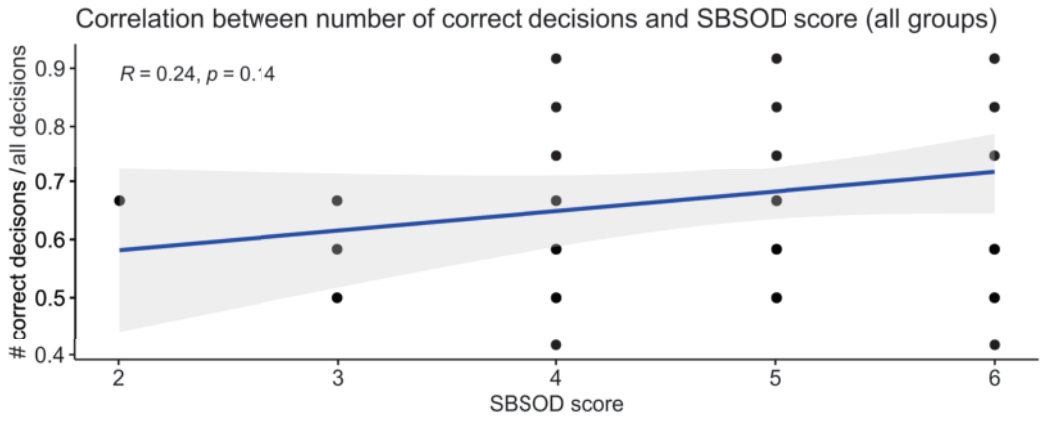



Figure 16: Correlation between SBSOD score and proportion of correct decisions (all groups)

In Figure 16 the regression line is illustrated with a blue line with the confidence interval displayed around it with a light gray colour. The data was not normally distributed, therefore "Spearman correlation coefficient" was calculated (Steland, 2007, p. 180, 181). With a correlation coefficient of 0.24 (visualised with the letter R) there is a weak positive correlation between the performance and the scoring in the spatial ability pre-test (Akoglu, 2018, p. 92). However this correlation is not significant (p = 0.14).

**Over all participants in the "Without" group**

Further the correlation of the performance was looked at over all participants performing under the "Without" group (Group 1). Again as an information support the participants in this group only had the exact route displayed in the map.

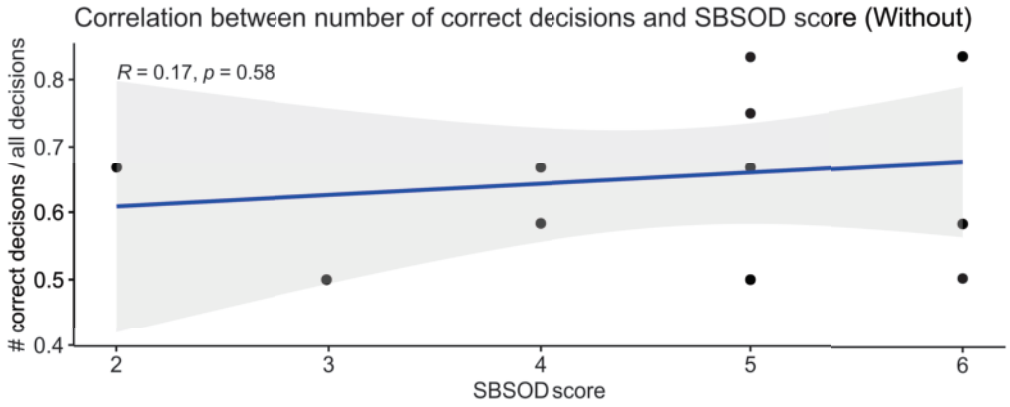



Figure 17: Correlation between SBSOD score and proportion of correct decisions ("Without" group)

In Figure 17 the regression line is illustrated with a blue line with the confidence interval displayed around it with a light gray colour. The data was normally distributed therefore "Pearson correlation coefficient" was calculated (Steland, 2007, p. 180, 181). With a correlation coefficient of 0.17 (visualised with the letter R) there is a weak positive correlation between the performance and the scoring in the spatial ability pre-test (Akoglu, 2018, p. 92). However this correlation is not significant (p = 0.58).

**Over all participants in the "Symbols" group**

Further the correlation of the performance was looked at over all participants performing under the "Symbols" group (Group 2). Again as an information support the participants in this group had the exact route displayed in the map and certain landmarks displayed as abstract symbols.

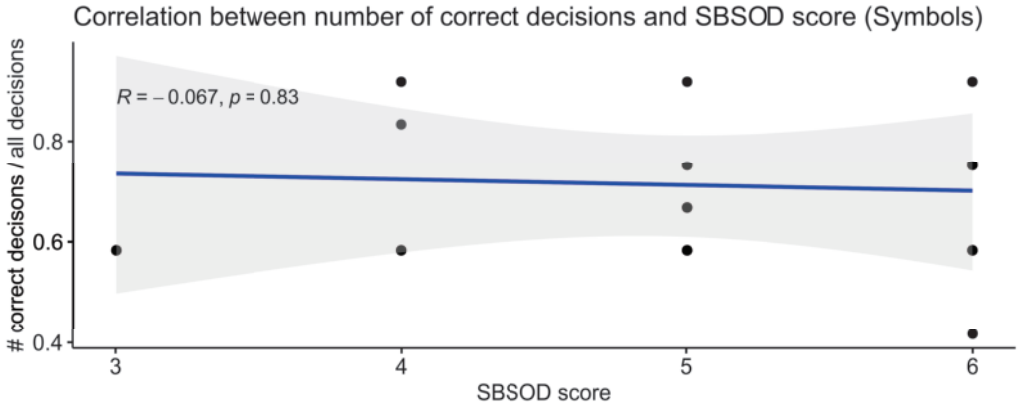



Figure 18: Correlation between SBSOD score and proportion of correct decisions ("Symbols" group)

In Figure 18 the regression line is illustrated with a blue line with the confidence interval displayed around it with a light gray colour. The data was normally distributed "Pearson correlation coefficient" was calculated (Steland, 2007, p. 180, 181). With a correlation coefficient of - 0.067 (visualised with the letter R) there is a very weak negative correlation, there is to say almost no correlation between the performance and the scoring in the spatial ability pre-test (Akoglu, 2018, p. 92). However this correlation is not significant (p = 0.85).

**Over all participants in the "Pictures" group**

Further the correlation of the performance was looked at over all participants performing under the "Pictures" group (Group 3). Again as an information support the participants in this group had the exact route displayed in the map and certain landmarks displayed as real-world pictures.

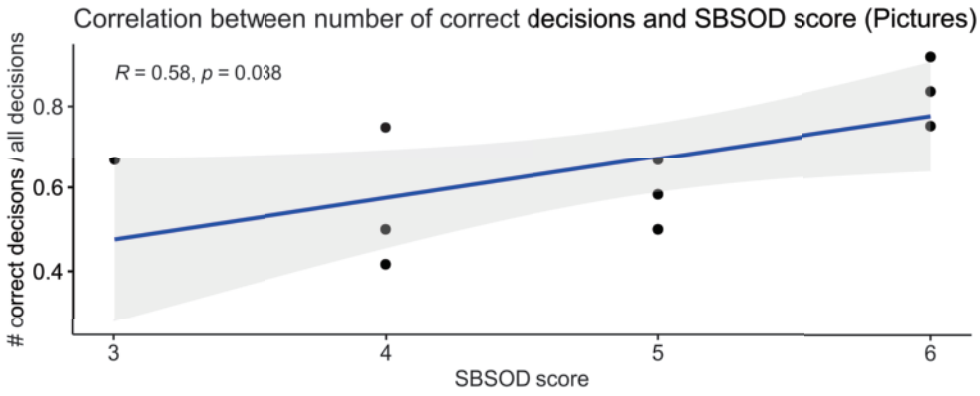



Figure 19: Correlation between SBSOD score and proportion of correct decisions ("Pictures" group)

In Figure 19 the regression line is illustrated with a blue line with the confidence interval displayed around it with a light gray colour. The data was normally distributed "Pearson correlation coefficient" was calculated (Steland, 2007, p. 180, 181). With a correlation coefficient of 0.58 (visualised with the letter R) there is a moderate or almost strong positive correlation between the performance and the scoring in the spatial ability pre-test (Akoglu, 2018, p. 92). This correlation is significant (p = 0.038).

### 4.2.2 Analysis of Route Decisions

In this section the three different groups ("Without" group / "Symbols" group / "Pictures" group) are compared on how they performed in the study. The criteria on how the participants performed here is again the ratio between the correct decisions in comparison over all decisions in the experiment. As a reminder on how the experiment worked, every participant was asked at twelve decisions and at seven of those landmarks were placed (only for "Symbols" and "Pictures" group), which were symbolised as abstract symbols or pictures in the "Symbols" respectively in the "Pictures" group. Also the participants in the "Without" group had to decide twelve times, but as already explained above did not have any landmark information in their map visualised. The procedure of the analysis of those data was that first visualisations of the data have been done with some general descriptive statistics parameters. In the following the requirements for the statistical tests got checked, namely for the "ANOVA" and the "Kruskal-Wallis" test (Universität Zürich, 2022c, p. 1) and (Universität Zürich, 2022a, p. 1). To achieve this the "Levene Test" for homogeneity of

variances and the "Kolmogorov-Smirnov" / "Shapiro-"Wilk" test for normality of the data was used (Glass, 1966, p. 188) and (Bee Wah and Mohd Razali, 2011, p. 21-33) and (R - Core Team, 2020, p. 1) and (Fox and Weisberg, 2019, p. 1).

As for the correlations before, the analysis was split up. Here it was split up regarding the different decisions. Firstly it was done for every participant over all decisions (12 in total), secondly it was done for every participant over all decision where there are landmarks visualised (7 in total) and thirdly it was done for every participant over all decisions where there are landmarks visualised (5 in total). The statistical analysis was done with the "Kruskal-Wallis" test, as the requirements for the "ANOVA" could not be met (Universität Zürich, 2022b, p. 1). The visualisations of those three different split ups are shown in the following.

**Over all participants over all decisions**

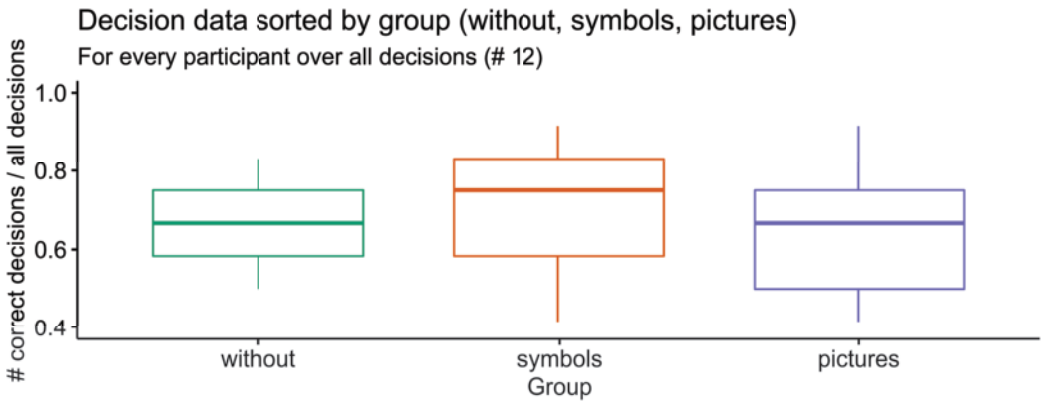



Figure 20: Decision data by group for all participants over all decisions

**Over all participants over all decisions where there are landmarks visualised**

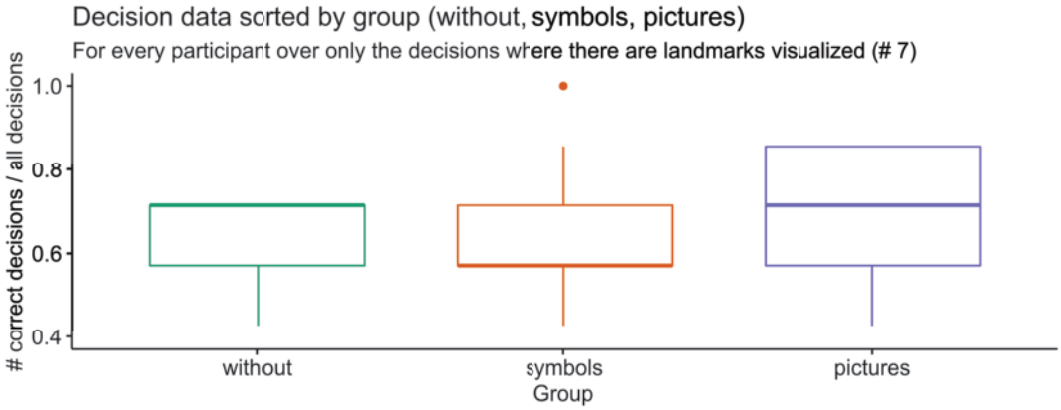



Figure 21: Decision data by group for all participants over all decisions where there are landmarks visualised

**Over all participants over all decisions where there are no landmarks visualised**

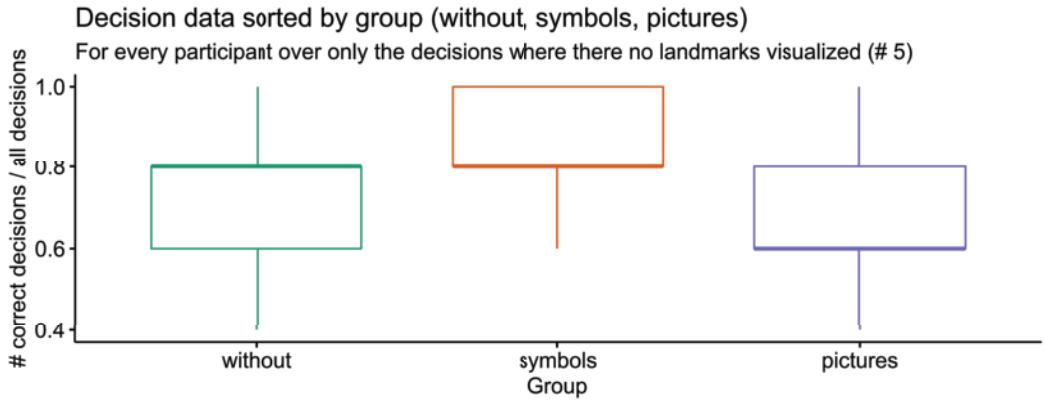



Figure 22: Decision data by group for all participants over all decisions where there are no landmarks visualised

The Figures 20, 21, 22 have the same structure, as on the y-axis the ratio between the number of correct decisions over all decisions is shown. The x-axis shows the three different groups to which the participants were assigned to. The box plots themselves are structured that the median is shown with a thicker line and that the box is limited at the upper and lower quartile of the data. The medians of the box plot for every split up group and for every group ("Without", "Symbols", "Pictures") are listed here shortly to be easier readable instead of graphics.

| **Split up group** | **Median values of the performance** | | | |
|---|---|---|---|---|
| All decisions (# 12) | Without: 0.67 | Symbols: 0.75 | Pictures: 0.67 | Random: 0.33 |
| Decisions with landmarks (# 7) | Without: 0.71 | Symbols: 0.57 | Pictures: 0.71 | Random: 0.33 |
| Decisions without landmarks (# 5) | Without: 0.8 | Symbols: 0.8 | Pictures: 0.6 | Random: 0.33 |

Table 8: Short overview over the collected data (medians)

The medians above represent the ratio value on how many decisions have been correct over the defined decisions for all the participants split up into the three groups ("Without", "Symbols" and "Pictures"). To give an idea on how the values should be understood, an example is illustrated. Taken the first value in Table 8 for the row "all decisions" it can be seen the number 0.67 and the group association "Without" group. The number of 0.67 should be understood that over all decisions the participants performing in the "Without" group the correct decision was taken in 67 % of the cases (median) or differently formulated, the participants took in 67 % the correct decision. The other values should be understood according to this schemata. If now those values are compared to the random decision, it can be stated that for all the three split up groups the values for every group is much higher than the value if they would choose random at every decision.

In addition to that it can be stated that looking over all decisions the participants in the "Symbols" group performed the best and the participants in the "Without" and "Pictures" group performed slightly

worse. When looking only at the data of the decision where there have been landmarks symbolised the participants in the "Without" and the "Pictures" group performed better. Finally, it was looked at only over the decisions where there have been no landmarks symbolised, even though this is not as meaningful as the others the participants of the "Without" and "Symbols" group performed best. After the visualisation and some descriptive statistics, the question was to find out if there is a significant difference between the groups in the number of correct decisions over all decisions. The statistical analysis was done with the "Kruskal-Wallis" test, as the requirements for the "ANOVA" could not be met (Universität Zürich, 2022b, p. 1). That applies for all the three data split ups, in more detail the data over all decisions, the data over decisions with only landmarks and the data over decisions with no landmarks. This test investigates as above if one of the three groups ("Without", "Symbols", "Pictures") performed significantly better/worse than other. The results of the "Kruskal-Wallis" tests showed the following p-values for the different split up groups.

| **Split up group** | **Test result of "Kruskal-Wallis"** |
|---|---|
| All decisions (# 12) | p-value = 0.5876 |
| Decisions with landmarks (# 7) | p-value = 0.873 |
| Decisions without landmarks (# 5) | p-value = 0.2343 |

Table 9: P-values for the "Kruskal-Wallis" test for the decision data

This means that the hypothesis that there is a significant difference between the three groups ("Without" group, "Symbols" group, "Pictures" group) cannot be accepted for each of the split up groups. Even though there is no significance difference there can be seen some tendencies on which group performed a bit better. More on that will be explained in the discussion section.

### 4.2.3 Analysis of Single Decision Points

In this subsection the three different groups ("Without" group / "Symbols" group / "Pictures" group) or in other words the participants performing in these groups are compared on how they performed in the study. The criteria on how the participants performed here is for every single decision how many times it was decided correctly and how many times incorrectly. In other words in this subsection it is looked at for every single decision where there have been landmarks (decisions 3, 4, 5, 8, 9, 10 and 11) visualised if there is a difference between the three groups "Without" group / "Symbols" group / "Pictures" group). The statistical procedure is exactly the same as in the chapter 4.2.2, using either the "ANOVA" or the "Kruskal-Wallis" test. For the sake of clarity, only the p-values of those tests are shown in this chapter.

In Table 10 the results are illustrated where only the performance of every single decision where landmarks have been visualised are being shown. Only the mean of the ratio of the correct decisions over incorrect decisions for all participants for every specific is displayed and not a graphic as done above, due to overview reasons. Here the mean is used instead of the median in the other result analyses, because, the value for every decision is either 0 or 1 (0 if correct, 1 if incorrect). To understand the table for example for the decision three in 84.6 % of the cases the participants in the "Pictures" group have taken the correct direction at this specific decision point. The other values should be understood according to the same scheme. One can see that in the earlier decisions, participants in the "Without" group tend to perform slightly worse than those in the "Symbols" group and the "Pictures" group. This changes, however, when one looks at

the later decisions, where one can see that the participants in the "Without" group perform better than those in the "Symbols" group and the "Pictures" group. More on that will be explained in the discussion section. Additionally, it has to be taken into account that the value of the standard deviation is relatively high, indicated by sd.

In the column on the far right it is additionally illustrated what the p-value of the above mentioned "Kruskal-Wallis", as the requirements for an "ANOVA" were not met (Universität Zürich, 2022b, p. 1). A value smaller than 0.05, and therefore a significant value can only be seen for decision nine, where the participants performing under the "Without" group and under the "Symbols" group performed significantly better at this decision point regarding on how many correct over incorrect direction decisions have been made.

| **Decision (only the ones where landmarks are displayed)** | **Mean of the ratio of the correct decisions over incorrect decisions for this specific decision; sd = standard deviation** | **p-value** |
|---|---|---|
| Decision 3 (Landmark 1) | • Without: 0.462 (sd: 0.519)<br>• Symbols: 0.615 (sd: 0.506)<br>• Pictures: 0.846 (sd: 0.376) | 0.1271 |
| Decision 4 (Landmark 2) | • Without: 0.692 (sd: 0.48)<br>• Symbols: 0.615 (sd: 0.506)<br>• Pictures: 0.769 (sd: 0.439) | 0.7034 |
| Decision 5 (Landmark 3) | • Without: 0.462 (sd: 0.519)<br>• Symbols: 0.538 (sd: 0.519)<br>• Pictures: 0.615 (sd: 0.506) | 0.7396 |
| Decision 8 (Landmark 4) | • Without: 0.385 (sd: 0.506)<br>• Symbols: 0.692 (sd: 0.480)<br>• Pictures: 0.538 (sd: 0.519) | 0.2993 |
| Decision 9 (Landmark 5) | • Without: 1 (sd: 0)<br>• Symbols: 1 (sd: 0)<br>• Pictures: 0.615 (sd: 0.506) | **0.003742** |
| Decision 10 (Landmark 6) | • Without: 0.769 (sd: 0.439)<br>• Symbols: 0.692 (sd: 0.48)<br>• Pictures: 0.692 (sd: 0.48) | 0.8839 |
| Decision 11 (Landmark 7) | • Without: 0.615 (sd: 0.506)<br>• Symbols: 0.462 (sd: 0.519)<br>• Pictures: 0.538 (sd: 0.519) | 0.7396 |

Table 10: Overview table of the analysis for all single decisions where landmarks have been visualised (means)

### 4.2.4 Decision and SBSOD Score

In addition to only look at the performance of the participants during the main study where it was looked at how many correct over all decisions they had, in this chapter also the factor of the performance in the spatial ability pre-test was included to investigate if there is a difference between the three groups. As in this case it is not only one factor but rather two factors (score in the main study and score in the spatial ability pre-test) the "Kruskal-Wallis" test is not suitable anymore and therefore an extension of this test which also is an non-parametric procedure had to be taken, which was found in the "Scheirer-Ray-Hare" test (Scheirer et al., 1976, p. 429-434) and (Mangiafico, 2022, p. 1).

For the inclusion of the value of the performance of the spatial ability pre-test a categorisation was done into two groups. This split was based on the median of the results of the spatial ability pre-test which was at around 5. Therefore, the split was done at this value so that one group are the participants who achieved values smaller than 5 and the other group are the participants who achieved values higher than 5 in the spatial ability pre-test for the overall score. The factor for the performance in the spatial ability pre-test is therefore SBSOD factor. The results which resulted from the "Scheirer-Ray-Hare" test were the following visualised through the generated Tables 11 and 12.

| **Considered factors** | **p-value** |
|---|---|
| Group | 0.5876 |
| SBSOD factor | 0.2603 |
| Group and SBSOD factor | 0.58547 |

Table 11: Results of "Scheirer-Ray-Hare" test for all decisions

| **Considered factors** | **p-value** |
|---|---|
| Group | 0.87304 |
| SBSOD factor | **0.01301** |
| Group and SBSOD factor | 0.26781 |

Table 12: Results of "Scheirer-Ray-Hare" test for the decision where there are landmarks visualised

In the Tables 11 and 12, the p-values are listed on the right side of the table. Table 11 shows the calculations where all decisions were taken into account. Table 12 shows the calculations where only the decisions where landmarks were visualised were taken into account. For both one can see three p-values, the first row compares the data on how often the correct decision was made based only on the group assignment ("Without" group, "Symbols" group and "Pictures" group), the second row compares the data based only on the results from the spatial ability pre-test and the third row combines both and says whether the two together had an influence on the performance of the participants. The results show that only one value is significant, i.e. less than 0.05, namely for the landmark decisions, that the result from the spatial ability pre-test had a significant role on the performance of the participants. More on that will be explained in the discussion section.

### 4.2.5 Analysis of Confidence in Decisions

The three different groups ("Without" group / "Symbols" group / "Pictures" group) or in other words the participants performing in these groups are compared on how they performed in the study. The criteria on how the participants performed here is how confident the participants were with their decisions. The statistical procedure is exactly the same as in the chapter 4.2.2. The statistical analysis was done with the "Kruskal-Wallis" test, as the requirements for the "ANOVA" could not be met (Universität Zürich, 2022b, p. 1). As already illustrated in the method section the participants were asked to state after every decision how confident they were with their decision. They had three possibilities (unsure, neutral and sure). Those possibilities were encoded for the analysis into:

- unsure: value 1
- neutral: value 2
- sure: value 3

As in the chapters before, the analysis was split up. Here it was split up regarding the different decisions. Firstly it was done for every participant over all decisions (12 in total), secondly it was done for every participant over all decision where there are landmarks visualised (7 in total) and thirdly it was done for every participant over all decisions where there are landmarks visualised (5 in total).

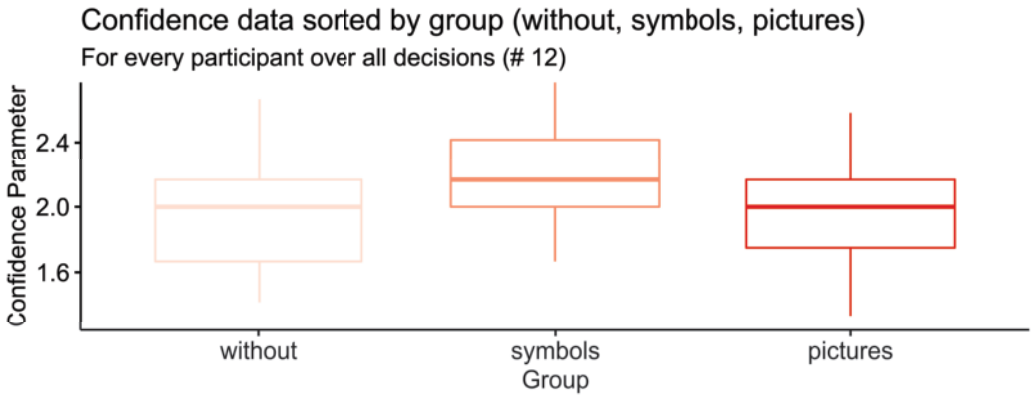



Figure 23: Confidence data by group for all participants over all decisions

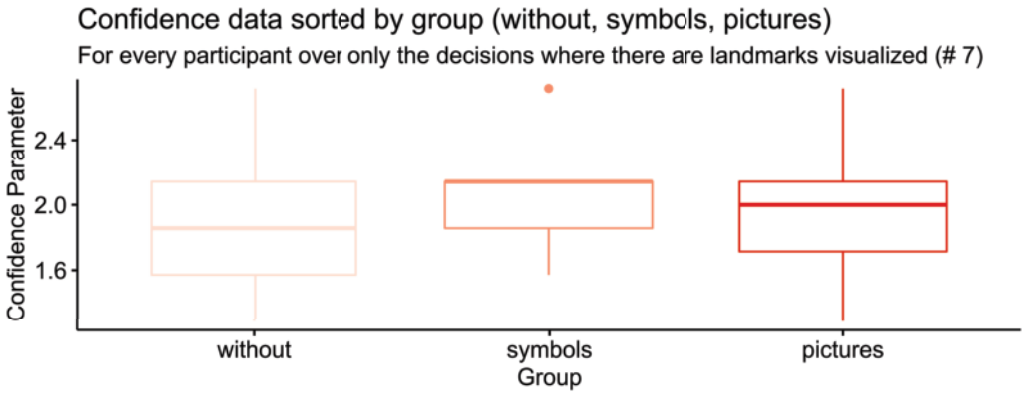



Figure 24: Confidence data by group for all participants over all decisions where there are landmarks visualised

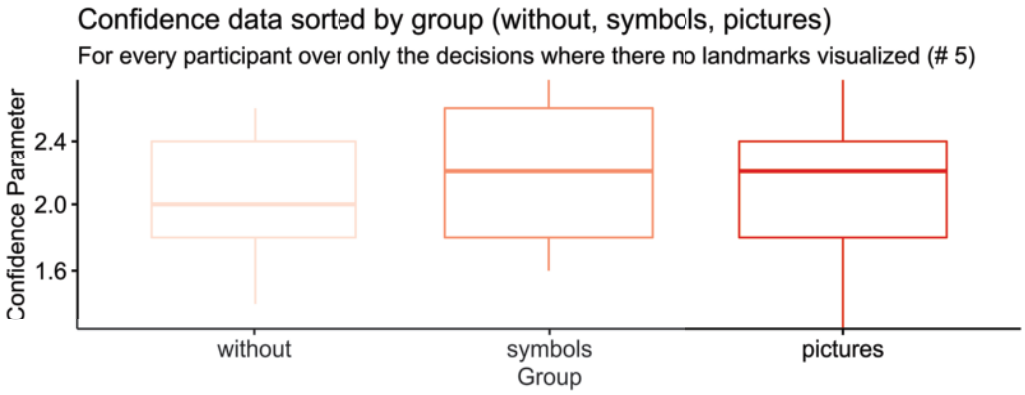



Figure 25: Confidence data by group for all participants over all decisions where there are no landmarks visualised

Figures 23, 24, 25 have the same structure, as on the y-axis the confidence parameter is shown. The x-axis shows the three different groups to which the participants were assigned to. The box plots themselves are structured that the median is shown with a thicker line and that the box is limited at the upper and lower quartile of the data.

The medians of the box plot for every split up group and for every group ("Without", "Symbols", "Pictures") are listed here shortly to be easier readable instead of the graphic. The values should be understood firstly that generally the higher the value, the more confident the people felt in their decisions. The values in Table 13 are generated from the three possibilities above, as value 1 (unsure), value 2 (neutral) and value 3 (sure). The values should be understood in the scheme that for example the median of the confidence for participants performing in the "Without" group over all decisions was 2 (neutral). The other values should be looked at similarly to this schema.

| **Split up group** | **Median values of the confidence** | | |
|---|---|---|---|
| All decisions (# 12) | Without: 2 | Symbols: 2.17 | Pictures: 2 |
| Decisions with landmarks (# 7) | Without: 1.86 | Symbols: 2.14 | Pictures: 2 |
| Decisions without landmarks (# 5) | Without: 2 | Symbols: 2.2 | Pictures: 2.2 |

Table 13: Short overview over the collected confidence data (medians)

When looking at the data it can be seen that the medians of the confidence of the participants in the "Symbols" group are always the highest or once as high as the participants in the "Pictures" group. This value represents, as already explained further up, how confident the participants are with their decision. So, there is a tendency that the participants in the "Symbols" group have been more confident with their decisions, but more on that in the discussion section.

The results of the "Kruskal-Wallis" tests showed the following p-values for the different split up groups. This means that the hypothesis that there is a significant difference between the three groups ("Without" group, "Symbols" group, "Pictures" group) regarding the confidence in the decisions of the participants cannot be accepted for each of the split up groups. Even though there is no significance difference there can be seen some tendencies on which groups participants have been a bit more confident. More on that will be explained in the discussion section.

| **Split up group** | **Test result of "Kruskal-Wallis"** |
|---|---|
| All decisions (# 12) | p-value = 0.3645 |
| Decisions with landmarks (# 7) | p-value = 0.2988 |
| Decisions without landmarks (# 5) | p-value = 0.3919 |

Table 14: P-values for the "Kruskal-Wallis" test for the confidence data

#### 4.2.6 Analysis of Decision Time

The three different groups ("Without" group / "Symbols" group / "Pictures" group) or in other words the participant performing in these groups are compared on how they performed in the study. The criteria on how the participants performed here is the amount of time they needed to tell the way to go between the video stopped and the time the direction was told to the study conductor. The statistical procedure is exactly the same as in the chapter 4.2.2. The statistical analysis was done with the "Kruskal-Wallis" test, as the requirements for the "ANOVA" could not be met (Universität Zürich, 2022b, p. 1).

As in the chapters before, the analysis was split up. Here it was split up regarding the different decisions. Firstly, it was done for every participant over all decisions (12 in total), secondly it was done for every participant over all decision where there are landmarks visualised (7 in total) and thirdly it was done for every participant over all decisions where there are landmarks visualised (5 in total).

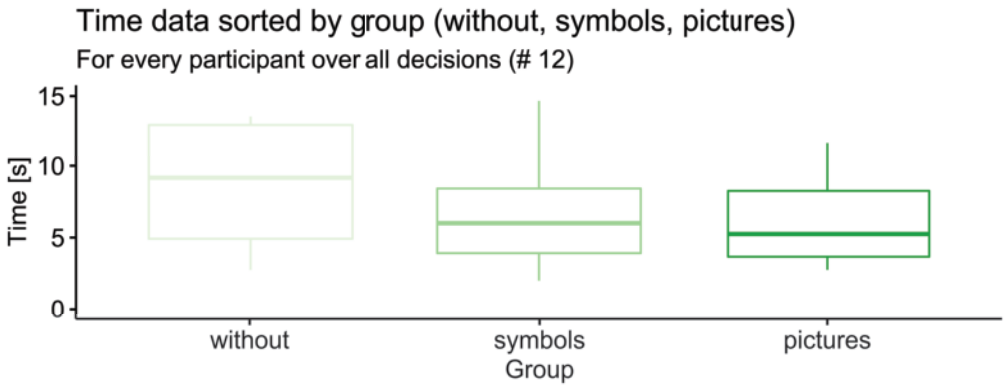



Figure 26: Time data by group for all participants over all decisions

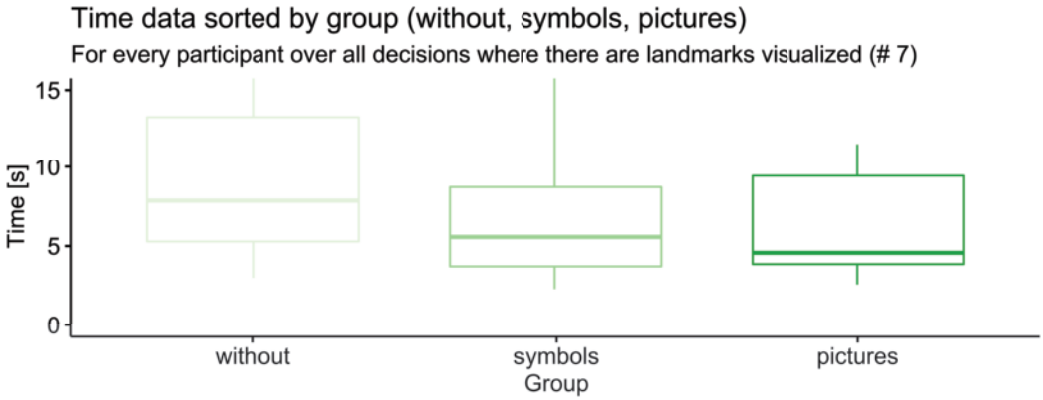



Figure 27: Time data by group for all participants over all decisions where there are landmarks visualised

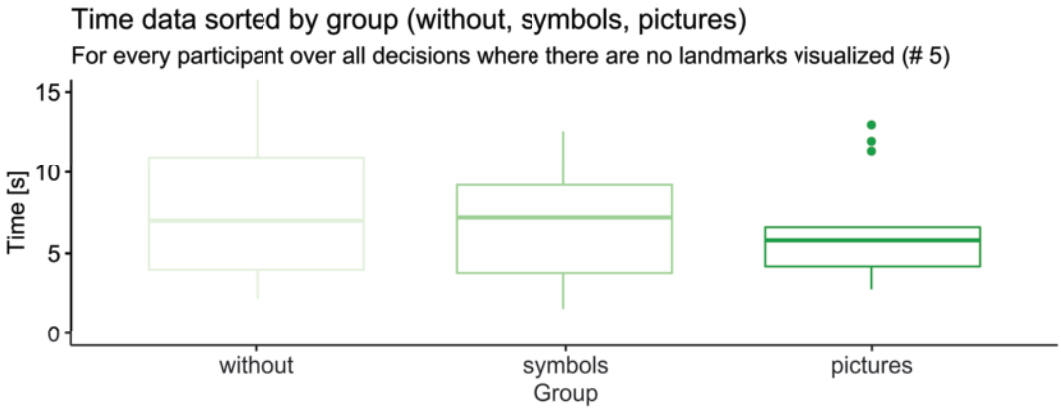



Figure 28: Time data by group for all participants over all decisions where there are no landmarks visualised

Figures 26, 27, 28 have the same structure, as on the y-axis the decision time is shown. The x-axis shows the three different groups to which the participants were assigned to. The box plots themselves are structured that the median is shown with a thicker line and that the box is limited at the upper and lower quartile of

the data. The medians of the box plot for every split up group and for every group ("Without", "Symbols", "Pictures") are listed here shortly to be easier readable instead of the graphic. The values should be understood in the scheme that for example the median of the decision time for participants performing in the "Without" group over all decisions was 9.17 s. The other values should be looked at similarly to this schema.

| **Split up group** | **Median values of the time in seconds** | | |
|---|---|---|---|
| All decisions (# 12) | Without: 9.17 s | Symbols: 6 s | Pictures: 5.25 s |
| Decisions with landmarks (# 7) | Without: 7.86 s | Symbols: 5.57 s | Pictures: 4.57 s |
| Decisions without landmarks (# 5) | Without: 7 s | Symbols: 7.2 s | Pictures: 5.8 s |

Table 15: Short overview over the collected time data (medians)

When looking at the data it can be stated that the in all three split up groups there is a tendency that the participants in the "Without" group had longer decision times than the participants in the "Symbols" and the "Pictures" group. In addition to that the participants in the "Pictures" group had slightly less decision time than the participants in the "Symbols" group. More on that will be explained in the discussion section.

The results of the "Kruskal-Wallis" tests showed the following p-values for the different split up groups. This means that the hypothesis that there is a significant difference between the three groups ("Without" group, "Symbols" group, "Pictures" group) regarding the time of the decisions of the participants cannot be accepted for each of the split up groups. Even though there is no significance difference there can be seen some tendencies on which groups participants have been a bit more confident. More on that will be explained in the discussion section.

| **Split up group** | **Test result of "Kruskal-Wallis"** |
|---|---|
| All decisions (# 12) | p-value = 0.3638 |
| Decisions with landmarks (# 7) | p-value = 0.388 |
| Decisions without landmarks (# 5) | p-value = 0.6927 |

Table 16: P-values for the "Kruskal-Wallis" test for the time data

## 4.3 Results Post-study Questionnaire

In this section the results of the post-study questionnaire get illustrated. As already stated above the questionnaire took place in the "questionnaire phase" which chronologically was at the end of the experiment. The questionnaire has been set up with Google Forms. The whole questionnaire can be seen in the appendix under chapter F. The following questions have been asked in the questionnaire, but not every participant had to answer all the questions, it depended on the group they were assigned to ("Without" group, "Symbols" group or "Pictures" group). In Table 17 the questions and which participants had to answer those are listed.

| **Number of question** | **Group which had to answer the question** | **Question phrase** |
|---|---|---|
| Question 1 | "Without" group / "Symbols" group / "Pictures" group | Please state whether the landmarks were shown as abstract symbols or as pictures on your map? |
| Question 2 | "Symbols" group / "Pictures" group | How much did the display and the design of the visualised landmarks in the map help you in recognising the actual landmarks in the video [1 = not at all, 5 = very much]? |
| Question 3 | "Without" group / "Symbols" group / "Pictures" group | Which landmarks in the video did you find most prominent? |
| Question 4 | "Symbols" group / "Pictures" group | Did the display of landmarks in the map help you in increasing your a priori spatial learning process of the route (i.e., remember the turns to take) [1 = not at all, 5 = very much]? |
| Question 5 | "Symbols" group / "Pictures" group | Which of the landmarks helped you the most for solving the navigation task? |
| Question 6 | "Symbols" group | How accurate did the symbols represent the landmarks shown in reality [1 = not at all, 5 = very much]? |
| Question 7 | "Symbols" group | Which symbols did the reality represent best? |
| Question 8 | "Without" group / "Symbols" group / "Pictures" group | In a routing app (such as Google Maps), would you find it useful if landmarks were displayed as symbols or images [1 = not at all, 5 = very much]? |
| Question 9 | "Without" group / "Symbols" group / "Pictures" group | Do you want to add something regarding the navigation task (i.e. have you lost the orientation at some point or influenced by something (i.e. dizziness)? |

Table 17: Overview on which group had to answer which question.

Now every question and its result get illustrated and analysed shortly to have an overview on what the results from the post-study questionnaire looked like.

### 4.3.1 Explanation of the Questions and Answers

Question 1

**Please state whether the landmarks were shown as abstract symbols or as pictures on your map?**

The first question was an organisational question to track to which group every specific participant belonged. So the participants could choose from three options (Pictures, Symbols, None) to which group they belonged. This allocation was based on what was shown on the map, respectively in which of the three groups ("Without" group / "Symbols" group / "Pictures" group), which were explained above, they were allocated. Resulting that this question was answered by all 39 participants. Only a single option could be chosen and the question had to be answered.

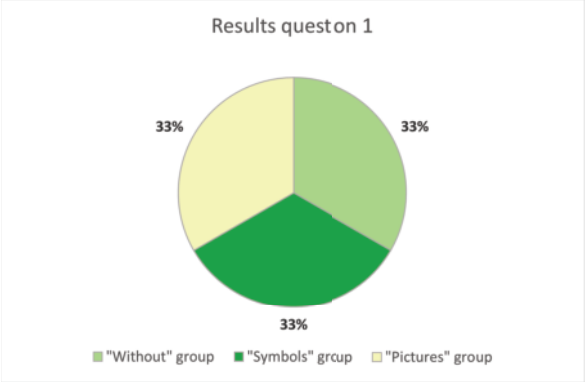



Figure 29: Distribution of participants in the study

Question 2

**How much did the display and the design of the visualised landmarks in the map help you in recognising the actual landmarks in the video [1 = not at all, 5 = very much]?**

This question was answered by the participants who were associated in the "Symbols" group or the "Pictures" group. Spoken in numbers, 26 participants answered this question. This question was whether the display and the design of the visualised landmarks helped the participants in recognising them in the video. Only a single option could be chosen and the question had to be answered. 2 people (7.7 %) gave the answer that it did not help at all, 5 people (19.2 %) wrote that it did not help, 6 (23.1 %) people voted neutral, 12 (46.2 %) people wrote that it helped and only 1 person (3.8 %) voted that it helped very much. It can be seen a tendency that the display and design of the landmarks in the map did help the participant in the recognising process during the video.

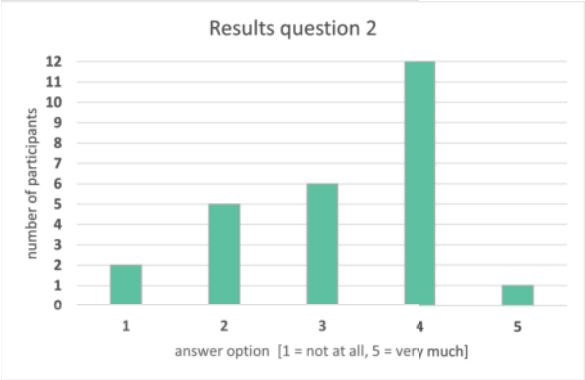
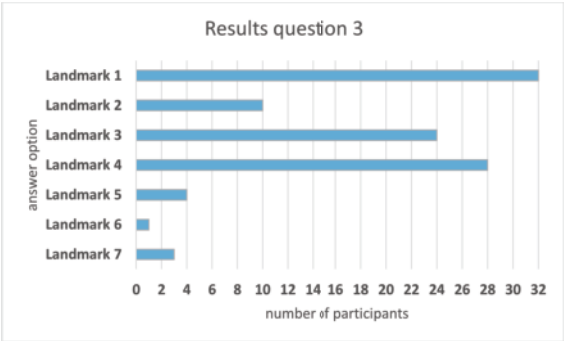



Figure 30: Post-study questionnaire results for question 2

Question 3

**Which landmarks in the video did you find most prominent?**


(a) Possible landmark options to choose




(b) Results of the possible landmark options

Figure 31: Post-study questionnaire results for question 3

The third question was answered by all the 39 participants as the question was about the landmarks seen in the video and which of those were most prominent. For this question at least one option had to be chosen but also multiple options could be selected. The landmark one was selected 32 times, the landmark two 10 times, the landmark three 24 times, the landmark four 28 times, the landmark five 4 times, landmark six once and landmark seven 3 times. It is noticeable that the first four landmarks were chosen much more often than the last three and that landmarks one, three and four were chosen by far the most.

Question 4

**Did the display of landmarks in the map help you in increasing your a priori spatial learning process of the route (i.e., remember the turns to take) [1 = not at all, 5 = very much]?**

This questions was answered by participants who were associated in the "Symbols" group or the "Pictures" group, so again by 26 participants. Only one option could and had to be selected. This question was whether the display of the landmarks helped the participant in increasing their a priori spatial learning process of the route, or in other words, remember the turns to take. 0 participants (0 %) chose the option that it did not help at all. 7 participants (26.9 %) checked the option that it did not help. 4 participants (15.4 %) choose the neutral option. 10

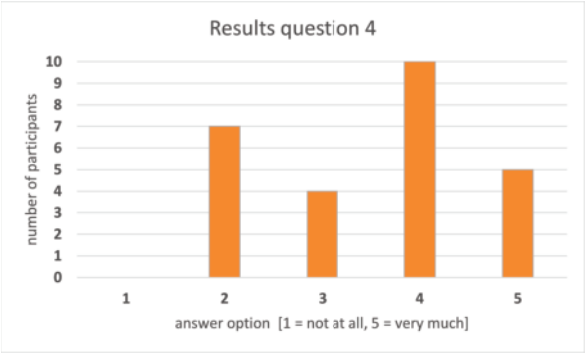


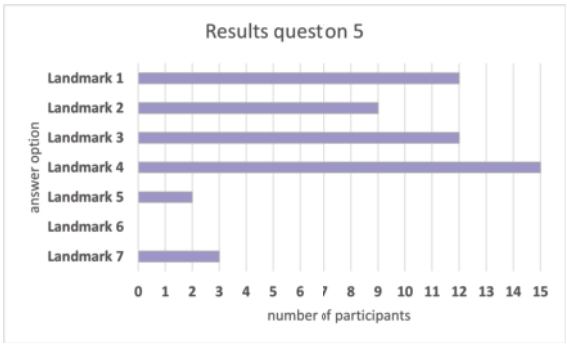

Figure 32: Post-study questionnaire results for question 4

participants (38.5 %) checked the option that it did help and 5 participants (19.2 %) selected the option that it did help very much. It is therefore a tendency visible that it did help to increase the a priori spatial learning process, as over 50 % of the participants stated that it helped somehow.

Question 5

**Which of the landmarks helped you the most for solving the navigation task?**


(a) Possible landmark options to choose




(b) Results of the possible landmark options

Figure 33: Post-study questionnaire results for question 5

This questions was answered by participants who were associated in the "Symbols" group or the "Pictures" group, so again by 26 participants. Multiple options could be selected and at least one had to be selected. The landmark one was selected 12 times, the landmark two 9 times, the landmark three 12 times, the landmark four 15 times, the landmark five 2 times, landmark six 0 times and landmark seven 3 times. It is noticeable that the first four landmarks were chosen much more often than the last three and that landmarks one, three and four were chosen the most.

Question 6

**How accurate did the symbols represent the landmarks shown in reality [1 = not at all, 5 = very much]?**

Question six was only for participants who were associated with the "Symbols" group. Therefore only 13 participants answered this question. Only one option could and had to be selected. The question was about how accurate the symbols represented the landmarks shown in reality. 1 participant (7.7 %) chose the option that it did not represent it accurate at all, 7 participants (53.8 %) selected that it did not represent it accurate, 3 participants (23.1 %) remained neutral, 2 participants (15.4 %) choose that the symbols represented the landmarks accurate and 0 participants (0 %) choose the option that it represented very much accurate. As more than 60 % of the answers are saying that the symbols did not represent the landmarks accurate or not accurate at all, there is a tendency that the symbols could not represent the landmarks really accurate.

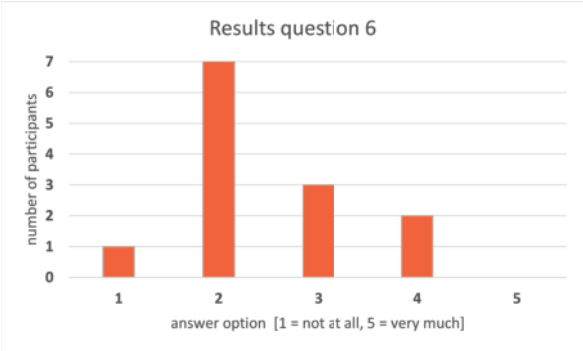
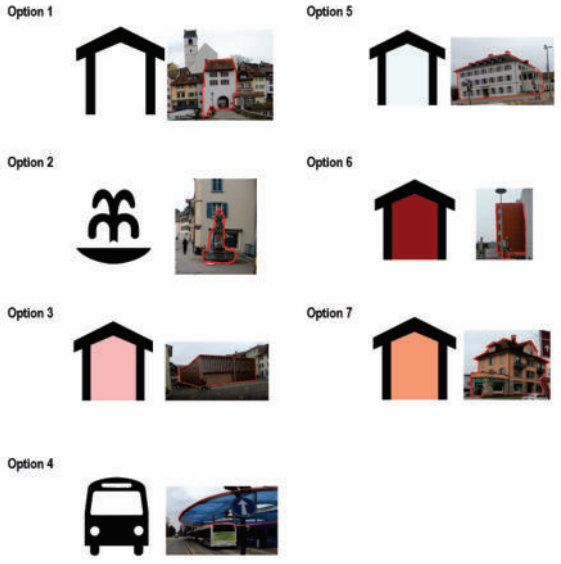


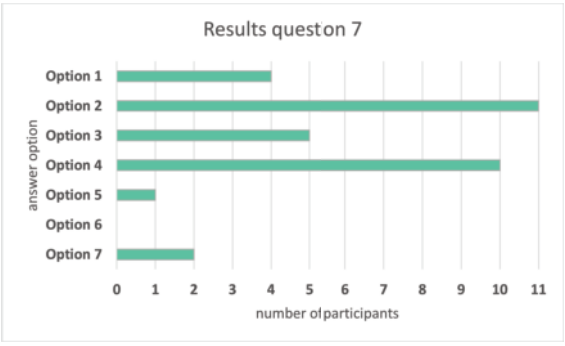

Figure 34: Post-study questionnaire results for question 6

Question 7

**Which symbols did the reality represent best?**




(a) Possible options to choose




(b) Results of the possible options

Figure 35: Post-study questionnaire results for question 7

This question was also only for the participants associated with the "Symbols" group. Resulting that also this question was only answered by 13 people. Multiple options could be selected and at least one had to be selected. The option one was selected 4 times, the option two 11 times, the option three 5 times, the option four 10 times, the option five once, option six 0 times and option seven 2 times. It is noticeable that the first four options were chosen much more often than the last three and that options two and four were chosen the most.

Question 8

**In a routing app (such as Google Maps), would you find it useful if landmarks were displayed as symbols or images [1 = not at all, 5 = very much]?**

The question 8 was for all participants, so in numbers for all 39 people. Only one option could and had to be selected. The question was about the participants find it useful if landmarks were displayed as symbols or images in a routing application. 1 participant (2.6 %) chose the option that it would not be useful at all, 2 participants (17.9 %) selected that it would not be useful, 7 participants (23.1 %) remained neutral, 14 participants (35.9 %) choose that it would be useful and 15 participants (38.5 %) choose the option that it would be very much useful. In the graph it can be seen, that a lot of participants would find it very much or much useful if landmarks were displayed as symbols or images. Over 70 % of the participants gave the answer of 4 or 5 in the voting which says that the people think it would be really helpful.

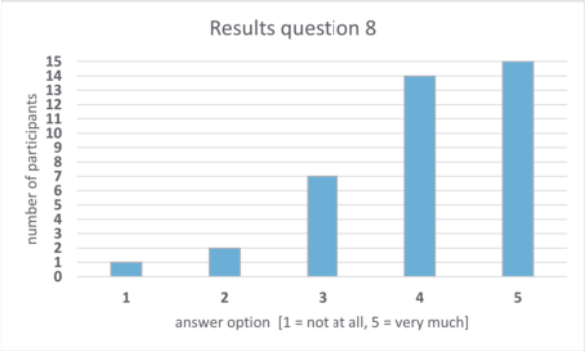



Figure 36: Post-study questionnaire results for question 8

Question 9

**Do you want to add something regarding the navigation task (i.e. have you lost the orientation at some point or influenced by something (i.e. dizziness)**

The last question was worded broadly so that participants could add any comments they may had, such as if something bothered them during the experiment or what their specific personal strategy was. As a result, various exciting remarks and comments came out also some mentioned verbally during or after the experiment. To structure the answers here a little bit they have been summarised somewhat in terms of their subject matter. In addition to that not the exact wording is written here but rather the content of the answers structured and integrated into a text. The exact given answers can be found in the appendix under chapter G.

**Strategy**

Different strategies have been mentioned in the post-study questionnaire. For example, a participant mentioned that she tried to remember all the direction changes with the specific direction and counted down

during the display of the video. Another strategy was to also remember the type of the streets, in more detail if they have been main roads or side roads or in a specific shape. This was also a help which could be read out of the base map. A participant mentioned specifically that he only tried to remember the "prominent" landmarks and turning points to have an overview over the whole route.

**Helping Points**

Certain points of help, which were also mentioned earlier, were brought up by the participants. So for example mentioned a participant that the signatures for cyclists on the road helped a little bit during the navigation. Another thing which helped some participants were the train-tracks at the end of the route which were also visible in the base map. Mentioned by several participants was the help of the landmarks during the navigation.

**Difficulties**

It was mentioned by several participants that the navigation in the middle of the route, when going through the old town of Aarau was especially difficult, as the streets and paths are really small, and the city is quite contorted there. The difficulty of judging the distances from the map into the reality was also stated by several participants. It was also stated by a participant that it was difficult that the rotation of the map could not be done. In addition to that the reading of the landmarks were sometimes difficult as their size could not be changed. By two participants it was mentioned that the landmark houses did not help as much as the other landmarks as it was difficult to remember.

**Distractions**

Two participants mentioned that they got a little bit dizzy during the navigation and that this probably influenced their performance a little bit.

# 5 Discussion

In this chapter, the two research questions presented at the beginning of the thesis are critically discussed and therefore the results are looked at in more detail. For this purpose, the results of the conducted study will be closely examined and analysed and additionally compared with the findings from the literature section. This section is structured, to answer the two research questions and then critically discuss the study. This is followed by a part, where the limitations of the study are being stated and illustrated what could be changed or added for further studies. Not only is the main study looked at in more detail, but also the spatial ability pre-test which was administered to each participant prior to the main study. It is important to state that the results of the two research questions can be explained by different reasons, which will be clarified in the subsections, but also that the design of the performed study is highly probable to having influenced the generated data.

As a reminder, the two research questions which have been illustrated in the beginning of the thesis and which formed the backbone throughout this study get shown here again.

**Research Question 1:**
How does the representation of local landmarks for a planned, urban bicycle route in a map application improve a priori spatial learning?

**Research Question 2:**
How does the symbolisation of local landmarks in a map application, in more detail simple, abstract symbols and real-world pictures, influence their memorability and also differ with their effect on the a priori spatial learning?

## 5.1 Answer to Research Question 1

The first research question looked at how the representation of local landmarks for a planned urban bicycle route in a map application can improve the a priori spatial learning. For this research question, various results have been generated, which are interesting to discuss. First of all, it can be stated that the results, which are presented in the chapter 4.2 indicate that in this experiment under the illustrated conditions no significant data was found, that the a priori spatial learning process was improved, when local landmarks were represented for a planned, urban bicycle route in a map application, either as symbols or as pictures. This is, because the p-values for all the split up groups were smaller than 0.05, meaning that there is no significant difference between the participants performing under the "Without" group (no landmarks visualised) and the participants performing under the "Symbols" group (landmarks visualised as symbols) and the "Pictures" group (landmarks visualised as pictures). An interesting idea or explanation for this was published by Montello (2017). Different studies state that landmarks are helpful in spatial cognition (Li, 2020, p. 432) and (Löwen et al., 2019, p. 11-13). The paper by Montello (2017), on the other hand critically challenges this view, as the focus is laid on the concept of landmarks. In other words, it is claimed that the effect of landmarks in the spatial and navigational context is not fully clarified and sometimes even exaggerated (Montello, 2017, p. 193-194). A key point is the definition of what a landmark exactly is and what can be included into its definition (Montello, 2017, p. 194-195). As also discussed earlier in the literature, this definition can be understood rather broad and is also influenced by different factors or

parameters (Montello, 2017, p. 194-195). An equally mentioned critic at the concept of landmarks is its location. It is questioned whether the landmark defines a location or if it is not the other way around that the place defines the landmark (Montello, 2017, p. 195-196). Regarding this debate and more on the choosing and displaying of the landmarks, or more generally possible explanations on why the landmarks did not have a significant effect in this experiment, will be addressed later in the discussion section with the critical review of the study design. Even though there is no significant result, some tendencies can be read from the graphics, which are also illustrated in the chapter 4.2. For example, if we look at the median values in the spilt group where the correct decisions were considered across all choices, we see that the value for the participants in the "Symbols" group is the highest with 0.75. This means that over all participants in this group and across all decisions (those where landmarks have been visualised and also those where they have not), the median of the participants taking the correct direction is in 75 % of all the decisions. The value for the "Without" group, where no landmarks have been visualised, is 67 %. As for the participants in the "Pictures" group, the value is 67 %. However, this is a very slight tendency and has to be looked at very carefully, because for example, when only looking at the decisions where landmarks have been visualised, the situation looks different, as the participants in the "Symbols" group only have 57 % of the decisions correct, compared to 71 % of the participants in the "Without" group and "Pictures" group.

Interesting data is shown when looking at the results of each single decision in the section 4.2.3. As a reminder, every single decision where landmarks were visualised is also analysed here, and the three groups are then compared for each individual decision. For those seven choices, only one decision (decision nine) delivered a significant difference between the participants performing in the "Without" group and the "Symbols" group (100 % of the participants hit the correct direction) in comparison with the participants performing in the "Pictures" group (61.5 % of the participants hit the correct direction). Even though, the other values have not been significant, a very interesting tendency can be seen and read from the data. The decisions are in chronological order and when looking at the decisions at the end of the route (decision nine, ten and eleven) it is clearly visible that the participants performing in the "Without" group performed better than the participants in the "Symbols" and the "Pictures" group. In the decisions at the beginning of the route (decision three, four, five, eight), the contrary can be seen, meaning that the participants in the "Without" group performed in almost all of those four decisions worse than participants in the "Symbols" and the "Pictures" group. A possible reason for that has been already mentioned in the literature part of this thesis. It is connected with the term of the cognitive load. The visualisation of landmarks, whether as symbols or pictures, can have an impact on the increase of the cognitive load and also on the working memory (Setlur et al., 2010, p. 1). The human brain is limited in the memorisation of information and thus such cognitive load, especially with the display of landmarks, where according to pre-results of a study, the optimal number of displayed landmarks is five (Cheng et al., 2018b, p. 3). This provides a possible explanation that for the later decisions on the route, the cognitive load of the participants was limited. Therefore, the displayed landmarks did not have the helping effect they might had for the decisions in the beginning of the route, where the participants in the "Symbols" and "Pictures" group performed better. One possible explanation is the help of the visualised landmarks, which has been explained in the literature part (Löwen et al., 2019, p. 11-13) and (Li, 2020, p. 432) and (Ben-Elia, 2021, p. 6). This assumption is also supported by the fact that in the post-study questionnaire, in questions three and five, which asked which landmarks were the most prominent and which helped the most, the first four of the seven landmarks were chosen substantially more often than the last three. This is also evident in the results section, where the results of the post-study questionnaire are presented. This better performance of the decisions in the

beginning of the route can also have different reasons. One interesting idea, that was not looked at in this work in detail, but could also contribute to the different results of those single decisions, is the location of the landmark in relation to the turning direction. For instance, if the landmark is positioned in the direction, which is being turned, it might be more helpful for navigation purposes, than if not (Albrecht and von Stülpnagel, 2021, p. 1-30). When comparing this with the results in the study, this cannot be fully confirmed, as the better navigation was not always correlating with the positioning of the landmark in the turning direction and not statistically investigated. Another idea for example is, that the participants often "learned" the route from the start point (mentioned in the post-study questionnaire in the last question). It could also be that the symbols or pictures at the beginning of the route would somehow have been more suitable to memorise the route. Especially the latter point would be highly interesting to focus on in further studies, to see which symbols or pictures and therefore which landmarks could perform better or worse in the memorising process. It would be particularly interesting to further analyse, whether the appearance or the function of a symbol is more useful for the symbolisation of a landmark, a point which was already discussed in the method part. Here the decision four and eight have been visualised with a symbol representing the function and not the appearance, namely the fountain and the bus station. Nevertheless, in both those decisions the participants of the "Symbols" group performed rather good, it is difficult to conclude from this, if the appearance or the function symbolisation helped more. The symbolisation and how landmarks are being shown will be discussed when the research question two will be answered, as in different studies, different symbolisations for landmarks are being used (Keil et al., 2020, p. 1-20) and (Zhu et al., 2022, p. 669-690). To find out more on this question, another study with the focus on this specific issue should be conducted.

Even though the statistical tests showed that there is no significant difference between the three groups, resulting that in this experiment under the proposed conditions there is no improvement of the a priori spatial learning process of the route. Interestingly, in the post-study questionnaire, the results of question number four and eight brought up different results. In question four the participants were asked to state, if the display of the landmarks helped them in increasing their a priori spatial learning process, which resulted that almost 60 % of the asked participants answered that it helped or helped a lot. Additionally, in the question eight it was asked if the participants would find it useful if landmarks were displayed as symbols or pictures. The results from these questions were quite clear, that the participants in general would find it very useful to have such landmarks displayed in a routing application. Spoken in numbers, over 70 % of the attendees who answered this question would find it helpful or very much helpful. This discrepancy between the actual performance and how people believe how they perform is a well-known phenomenon. The phenomenon is widely seen in different research areas, as for example in health science, finance or even transportation, namely "stated versus observed preferences" (Fifer et al., 2014, p. 164). It is basically articulated, that the assessment of the people often does not correspond exactly with the performance they have achieved or the real situation they are performing in (de Corte et al., 2021, p. 1096). Nevertheless, it is still often useful to take the stated preference and use it to forecast the behaviour (Whitehead et al., 2016, p. 610). An example to display the bias of stated preference versus observed preference is a transportation study by Fifer et al. (2014), where this effect could be seen (Fifer et al., 2014, p. 175-177). Coming back to the experiment performed in this study and the discrepancy between the assessment of the participants in the post-study questionnaire and the actual performance, this above explained effect can also be witnessed. Over 70 % of the participants would find it helpful or very much helpful, but in the performed study, under those specific conditions, this effect could not be as clearly seen as stated. Naturally, there are also other

factors which could contribute to that, for example that participants overestimated the effect and believed in the function of the landmarks display. This could be due to various reasons, one for example that the participants somehow wanted to support the idea of this master thesis.

### 5.1.1 Analysis of Decision Time

After the first analysis of the participants performance, two further aspects were listed in the results section, namely the decision time and confidence of the decision, which both have been measured additionally. First of all, it has to be stated that the statistical analysis, which was carried out in a similar procedure as before, did not reveal any significant differences between the groups regarding the decision time. Again, as an explanation, the decision time is the time between the stopping of the video and the telling of the direction. The participants performing in the "Without" group did not take significant longer or shorter time in the decision than the participants in the "Symbols" or "Pictures" group. But as before, some interesting tendencies can be discerned and are worth being looked at a bit closer here. In Table 15 it can be seen, that the decision time for the participants in the "Without" group is tending to be higher than the decision time for the participants in the "Symbols" and the "Pictures" group. A study by Bolton et al. (2015) looked also at this decision time, or in their paper mentioned as response time. The setting was similar, only was the experiment with augmented reality, contrary to this study (Bolton et al., 2015, p. 59). Similar results to this study were found in another paper, that decision time decreased when landmarks were visualised. (Bolton et al., 2015, p. 63). In another study by Parush and Berman (2004), an opposite effect could be measured, as there the navigation time was longer when landmarks have been visualised (Parush and Berman, 2004, p. 391, 392). Even though here it has to be stated, that the navigation time in total and not only the decision time was measured (Parush and Berman, 2004, p. 391, 392).

The reason for why in this experiment the decision time was shorter when landmarks have been displayed can have various contributing arguments. An idea could be that through the display of the landmarks the spatial knowledge increased (Credé, 2019, p. 6). Therefore, the participants could focus on the navigation and needed shorter decision times. So, through the acquired spatial learning process with the help of landmarks, there is a possibility that the answer could be given faster (Li, 2020, p. 432). On the other hand, an opposite effect was mentioned by Parush and Berman (2004), who stated, that the visualisation of landmarks lead to the further processing of information of the participants, which then can increase the time needed for navigating (Parush and Berman, 2004, p. 391, 392).

### 5.1.2 Analysis of Confidence in Decisions

First of all, it has to be stated that the statistical analysis, similar procedure done as before, brought up no significant difference between the three groups regarding the confidence of the decision has been found. The participants performing in the "Without" group did not feel significantly more or less confident in the decision than the participants in the "Symbols" or "Pictures" group. However, the attendees in the "Symbols" group and "Pictures" group showed a slight tendency to be equally or sometimes slightly more confident with their decision, which can be seen in Table 13. Similar to the discussion of decision time, this can be explained by the fact, that the spatial knowledge increased and the spatial learning process was improved (Credé, 2019, p. 6) and (Li, 2020, p. 432). Therefore, it could be that the confidence in the decisions increased.

For both the measurement of the time and the confidence and the mentioned tendencies and analysis it is interesting to state, that even though these parameters differed in the performance, which was the main measurement, there was no significant data seen and only tendencies could be read out of the data. To put it casually, it can be said that although certain participants of a specific group decide faster and with more confidence, the actual performance is the same as for the others.

## 5.2 Answer to Research Question 2

The second research question looked at how the symbolisation (symbols and real-world pictures) of local landmarks influences their memorability, in other words, if there are differences in the performance depending on the symbolisation. To answer this research question again here, firstly Table 8 in the section 4.2.2 can be consulted, where the medians are indicating on what the ratio of the correct answers in comparison with the incorrect answers were. Looking on the values for the "Symbols" group and the "Pictures" group, it can be seen that there is no significant difference between those two groups, respectively between the performances of the participants of those two groups under those experiment conditions. Looking at the exact numbers over all decisions, the participants performing in the "Symbols" group took in median the correct direction in 75 % of the times and the "Pictures" group participants in 67 % of the times. When only looking at the decisions where landmarks have been visualised, which for this research question is highly important, it can be seen, that the participants in the "Symbols" group performed worse (57 % correct) in comparison with the "Pictures" group (71 % correct).

Even though it is not significant, it is interesting to see, that an abstract symbol could under circumstances influence the memorability of a local landmark better than a real-world picture. This small tendency can be seen in Table 8 that the participants performing in the "Symbols" group performed slightly better, when looking over all decisions. The aspect that maybe an abstract illustration can lead to better navigation and orientation, was also found in a similar study, where it was stated that adding visual realism can also lead to overload of the cognitive possibilities (Çöltekin et al., 2018, p. 1-15). Nevertheless, it must be said that the data here also show an opposite effect, for example, that when considering the decisions where only landmarks have been shown, the participants who performed in the "Symbols" group were better than those in the "Pictures" group. Here the level of abstraction can be taken for an explanation, as a picture shows a higher degree of realism (Elias and Paelke, 2008, p. 12).

As also mentioned in the answer for the research question one, interesting data is shown when looking at the results of every single decision in the section 4.2.3. Focusing here on how the participants in the "Symbols" group and the "Pictures" group performed. Between those two groups there can be a difference spotted, that the participants performing in the "Pictures" group overall achieved more correct decisions than the participants performing in the "Symbols" group. This is especially true for the decisions at the beginning of the route and can also be associated with the theory of cognitive load, meaning that the display of landmarks in the end can lead to too much information memorising (Cheng et al., 2018b, p. 8). In decision three, for example, the participants in the "Symbols" group took the correct decision in 61.5 % and the participants in the "Pictures" group in 84.6 %. A possible reason therefore can be the higher degree of realism of the pictures in comparison to the symbols (Elias and Paelke, 2008, p. 12). This helped the participants identify the landmark better and therefore to use it better in the navigation process. A study by Zhu et al. (2022) also found similar results, where the study setting was comparable, namely that image-based symbols helped the participants the most, because landmarks could be found rapidly and also connected with the cognitive map (Zhu et al., 2022, p. 677). However, it must also be mentioned that other

reasons could have contributed to this result, such as the fact that the participants mostly learned the route from the beginning and that maybe the symbols and pictures in the beginning of the route have been more suitable.

Looking only at the symbols which have been used to display the landmarks, the question seven of the post-study questionnaire showed some interesting data. There it can be seen, that option two and four represent the reality the best and also option one and three were rather good in representing the landmark. It is therefore exciting that precisely these two landmarks in the option two and four represent the function rather than appearance of the landmark. They are for this reason rather working as a structural landmark according to literature (Sorrows and Hirtle, 1999, p. 46). Furthermore, one can see that the symbols, for example the fountain and the bus station, are very common and often used symbols, for instance the latter, which is being used in public transport. In answering this question, the landmarks at the end were not selected in large numbers, but this may also have to do with the fact that the participants did not remember them that much, as can be seen in answers three and five of the post-study questionnaire. The representation of the landmarks through the symbols has to be looked at critically, as can be seen from the answers of the question six in the post-study questionnaire. There it can be seen that the symbols did not represent the landmarks very well, apart from the spring and the bus station, which have been voted to represent the reality the best in question seven of the post-study questionnaire. Generally, it can be discussed that the landmarks as symbols and pictures are very diverse and that also the effect of every specific display is difficult to measure. It is highly important to focus on the display of those landmarks also with emphasis on the level of abstraction with the focus on cognitive load (Elias and Paelke, 2008, p. 12)(Setlur et al., 2010, p. 1).

### 5.2.1 Analysis of Decision Time

Similar as for research question one, also for the research question two the decision time and the confidence data can be compared, but here between the participants of the "Symbols" group and the participants of the "Pictures" group. First of all, it has to be stated that the statistical analysis, performed in a similar way as before, did not reveal any significant differences between the two groups ("Symbols" and "Pictures") regarding the decision time, that is, as already mentioned, the time between the stopping of the video and the indication of direction. Further, it can be seen in the Table 15 that the decision time for the "Pictures" group is smaller than the one from the "Symbols" group. This can have the reason, that through the more detailed representation of the landmark the spatial knowledge increased (Credé, 2019, p. 6). Therefore, the participants could answer faster. In other words, there is a possibility that the cognitive load was influenced through a more complex display (Setlur et al., 2010, p. 1). But also, the display of a real-world landmark helped in finding the specific landmark in the video faster. So therefore, a possible explanation was that the picture of the landmark could be recognised in the video in a fast way.

### 5.2.2 Analysis of Confidence in Decisions

First of all, it should be noted that the statistical analysis, similar procedure being done as before, brought up, that no significant difference between the two groups ("Symbols" and "Pictures") regarding the confidence of the decision has been found. The confidence data between the participants performing in the "Symbols" group and the participants performing in the "Pictures" group are very similar, with slightly more confident decisions in the "Symbols" group. Interestingly, this data is a bit contradictory to the time data. One possibility could be that the information displayed was too much information and that this made participants in the "Pictures" group more unsettled compared to participants in the "Symbols" group. A study by

Cöltekin et al. (2018) looked at a similar topic and concluded that added visual realism, can be demanding for people and add cognitive load (Çöltekin et al., 2018, p. 12). This may have been the case here, although it contradicts the shorter decision times mentioned in the subsection above.

## 5.3 Interpretation and Validation of the Spatial Ability Pre-Test

One further important aspect is to look critically at the spatial ability pre-test, which every participant did before performing in the main study. Because this test was the basis for the crucial division of the participants into the three experiment groups. As already stated in the method section, the Santa Barbara Sense of direction test (SBSOD) is likely to predict spatial abilities of individuals (Hegarty et al., 2002, p. 443). For this reason and additionally since it has been already used in other similar navigation studies, this test has been chosen (Ishikawa et al., 2008, p. 77). It will now be shortly presented what the mentionable points are, that the test was suitable, and what maybe could be changed.

First of all, when looking at the correlation graphics in the section 4.2.1, it can be seen that there is a slight correlation when looking at the data over all participants and across all groups that the better the score in the SBSOD was, the better also the performance (ratio of correct decisions over all decision) in the study of this thesis was. It can be cautiously concluded that the SBSOD performance and the task in the study are to some extent related. Another point to strengthen the assumption that the SBSOD was suitable for the conducted study are the results in the section 4.2.4, where the performance data is being looked at on two factors, namely the association with the group and also the score in the SBSOD. It can be seen in the Tables 11 and 12 that when looking at the results of the "Scheirer-Ray-Hare" test for the decisions where landmarks are visualised, the p-value is significant (smaller than 5 %) for the value "SBSOD factor", meaning that when looking at the performance, the result in the SBSOD test plays a crucial role and again it can be cautiously concluded, that the SBSOD and the task in the study are to some extent related. In order to also mention specific aspects, which could be changed or also that brought along certain uncertainties, the following points are considered worth mentioning. The SBSOD test was done by the participants online in a non-controlled setting that the attendees could decide on their own. For example, at home, at university or at work. Consideration could be given to performing the SBSOD as part of the experiment in a more "controlled" environment or even thinking about performing it on paper rather than online, which might be slightly different for the participants when comparing the results (Friedman et al., 2020, p. 809-812).

## 5.4 Reliability and Validity

Three important criteria which should also be looked at are the reliability, the validity and the objectivity. The former means that we basically find the same results when the result is repeated several times under the same conditions (Martin, 2008, p. 137). By performing different options for reliability tests after the study, this could be checked, which could be done in a further step for this master thesis experiment (Martin, 2008, p. 138). One of those options could be to perform a very similar test to the same people and after that, the correlation of the scores for every person are compared (Martin, 2008, p. 138). Validity, on the other hand, states, if whether what is meant to be measured is actually being measured (Martin, 2008, p. 138). An indication that the spatial ability pre-test could be a useful test of the participants' matching ability was shown by the correlations in the results section, where a slight positive association between the scores in the study and the spatial ability pre-test was found. Regarding the main study it can be divided between internal and external validity. Internal refers to the question if possibly other factors influenced the result of the

study, as for example the selection of participants, which also in this case might not be completely random, as a lot of the attendees were recruited from the university with a geographical background (Martin, 2008, p. 32-33). Other factors such as the procedure and conditions were also carefully examined and the settings and instructions were normalised. So, the aim was to have objectivity in the design of the conducted study. The effect of displayed local landmarks regarding the a priori spatial learning process should be measured here only with the display of such landmarks, where it is therefore important to critically evaluate, if this display is really the cause of the performance. It should be noted here that this significant effect could not be measured, but certain tendencies, which are explained above could be read out. Coming then to the external validity, which deals with whether the results can now be applied in a generalised way to other areas (Martin, 2008, p. 28). In light of the results in this study this generalisation should be done carefully and more research on the effect should be done, to then also further value the external validity.

## 5.5 Criticism of the Study Design / Limitations of the Study

The study carried out within the framework of this thesis entails some aspects that should be critically questioned. By no means is the study design, as it was implemented here within the framework of this master thesis, the best solution. On the contrary, some things became apparent during the implementation and analysis of the study, which would have to be resolved in a different way. These points are examined in more detail in the following section. The listed points below could all contribute to the fact that no significant difference could be found between no display of landmarks and the representation of landmarks as well as between the display of landmarks as symbols and pictures. But regarding the significance of the data, it is absolutely crucial to remember that the results have been generated under specific conditions and circumstances, and that there is a possibility, that the result would be different when some parameters would be changed.

### Choosing of the Participants

An important point which has to be critically discussed are the participants of the study. First of all, regarding the number of participants in the study, it should be noted that the number of 39 people is already a good number, however, it would have been interesting if more individuals had attended in the study to substantiate the results. Another crucial point to discuss is the geography background of a lot of the participants in the study. In the method part, it was already illustrated that around 70 % of the participants are either currently studying geography or have at some point in the past studied geography or a similar subject. The reason, why this can be important is that individuals who have this relationship to the study of geography are under certain circumstances not reflecting the majority of the people. It was the aim to randomly select the participants for the study to have a randomised sample (Martin, 2008, p. 28, 29). As the recruiting of participants was mainly done among friends and family, lot of them had connection to geography. The reason why this maybe could be a problem is that those people are probably more familiar with reading maps and navigation than the majority of the society, as this is often part of the study plan in geography. Therefore, it could be interesting to perform the study with people with no geographical relationship. To compare why such a characteristic or ability of a participant can influence the result, is the fact that also gender can have an influence on way-finding approaches (Lawton and Kallai, 2002, p. 389-401). Due to this gender difference in a study this has been carefully addressed, as only male or female participants were asked to perform in the study (Çöltekin et al., 2018, p. 5). Hence, the characteristic of

geographical study could have been addressed in a similar way. Even though this issue has been mentioned here, it is also dealt with in similar studies that geography students participate in such studies (Wilkening, 2010, p. 1-7).

**Choosing of the Route**

Another important point to mention is the choosing of the route for the study. The appropriate selection of the route was done with a small variant study, in which four possible routes were first reduced to the two most suitable ones and then a more detailed analysis was made between these last two remaining routes as to which would be most suitable for the planned study. Even though this variant study in combination with the pilot experiment helped in deciding which of the routes could be the most appropriate, the selection could have been done depending on a survey and a closer analysis. The fact, that the route might be a bit too simple, in other words, that also the "Without" group achieved rather good performance results, should be looked at under a critical light. This would then mean, that the difference between the participants in the "Without" group and in the "Symbols" and "Pictures" group would not be so clearly visible. It is rather difficult to find the most appropriate route for the study as a lot of aspects, like duration, distribution of landmarks, drive ability and last but not least the structure of the area (rural, urban, old town) has to be considered. Nevertheless, this is an important point, which should be investigated further and in more detail in similar studies. Perhaps one could then arrive at different results. Relating to the route, another critical issue to mention was the fact that in the web application the orientation of the perspective could not be changed, in other words, the map was always aligned to the north. This issue was mentioned by a few participants in the post-study questionnaire and might have influenced the performance of the attendees.

**Choosing and Display of the Landmarks**

Closely related to the aforementioned aspect of choosing the route, also the appropriate selection of landmarks is a difficult but rather crucial aspect. On the four possible routes various different landmarks could have been chosen. As already explained in the literature part, the definition of landmarks can be rather challenging, as almost any decision point in space or rather a bit more specific, certain spatial reference points can serve as a landmark (Sorrows and Hirtle, 1999, p. 39, 40) and (Sadalla et al., 1980, p. 516). Therefore, it can be challenging to decide on which landmarks should be selected and then displayed. For the choice the literature was consulted, based on the two criteria "visibility" and "saliency", those have been used to define which landmarks are being taken (Yesiltepe et al., 2021, p. 374, 404). For both there are some specific parameters which can be looked at, as for example, shape or colour of the object (Yesiltepe et al., 2021, p. 404). But as already stated in the method section it would have been useful if a small pre-study about the suitability of the landmarks could have been made with different participants to decide on which landmarks were most appropriate based on different people and not only one person. This idea can be supported, as it was seen in the post-study questionnaire, especially in questions three and five, that there are differences in how prominent or helpful the participants perceived the various landmarks to be. Generally spoken, it can be stated that a lot of landmarks taken are houses which somehow stand out due to their location or appearance. This should also be mentioned, as it would be interesting to find out if more variety in the selection of the landmarks should have been created. Regarding the choosing of the landmark another important point which has been mentioned in the post-study questionnaire by a few participants, was that other information, not only the landmarks helped them in navigating. So for example the streets and their course or also the influence of bigger features, like the train tracks, influenced their decisions, thus it was

difficult to only measure the influence of the landmarks. A study by Chrastil and Warren (2012) showed, that also other factors could influence the navigational knowledge, for instance distances and turning angles of a route (Chrastil and Warren, 2012, p. 19). There are also points worth discussing in the representation of the landmark on the map. For the symbolisation of the landmarks themselves in the map, there are likewise various different options, such as visualisation as three-dimensional objects or even entire maps, or else the possibility of visualising them with a pop-up window (Coors et al., 2005, p. 545 - 548) and (Xiao et al., 2020, p. 17). One key element which is crucial independent of the visualisation style is the readability for the user and how generalised the map should be (Dillemuth, 2005, p. 298, 299). So, under certain circumstances a generalised map can lead to more effective orientation than a real-world picture or aerial map view (Dillemuth, 2005, p. 298). In the conducted study this was basically ensured, as the map was not filled with other signs and information. Unfortunately, some software issues lead to the fact that the symbols and pictures could not be adjusted based on the zoom level, so one size had to be used for the different zoom levels. Therefore, those symbols and pictures appeared somewhat large when zooming in and vice versa when zooming out. In the post-study questionnaire this issue was mentioned by a few participants. Critically discussed here in regards of the symbols are the results from the post-study questionnaire, where the answers of the sixth question clearly show that the symbols could have been designed better to symbolise the landmarks. Furthermore, if the display of landmarks and its integration into map applications, for example Google Maps or Apple Maps would be done, then this question would become very important. The inclusion and display of such landmarks should as a result be done in a way that is relevant to the navigation task.

**Further Potential Critic**

Some minor aspects can be critically considered and possibly changed or examined in more detail in future. An example for that could be a user study to define how long the phase should last, in which the participants are asked to memorise the route. This could be determined by a smaller pre-study where this question could be investigated. A possible reason could be, that the longer the route is being looked at, the better also the route can be learned and the less the effect of landmarks are. The assumption of navigating with only the route path works, showed the participants performing under the "Without" group in this study, as the performance was somehow comparable to the performance in the two other groups. This was also monitored in a study with children navigating, where it was stated that the sequence and succession of turns is helping to navigate next to landmark information (Lingwood et al., 2015, p. 79). This can be a cue that the map study time can have an influence on the result, as that then possibly other route learning strategies emerge, when no landmarks are visualised. Another exciting aspect that could be considered is whether further studies in this subject area could be conducted in the real world or completely in a virtual world, where the parameters could be changed at will. In this way, it might be possible to have comparative results if further studies could be conducted under both conditions. Of course, it would also be worthwhile to consider changing the parameters and symbolisations in a virtual world. Last but not least, adjustments in the study setting regarding the issue if motion sickness are also worth discussing, as in the conducted study, a few participants mentioned minor signs of motion sickness and there could be a possibility that the results have been influenced by that. Therefore, this is also an important aspect to look at and to remember.

# 6 Conclusion and Outlook

Coming back to the problem situation at the begin of the thesis, where in an imaginary scenario a destination in an unknown area has to be reached with a bicycle. For this kind of spatial tasks often a map application is used to have a display of the route which has to be driven. The optimal way would be to be able to remember the entire route and memorise it, so that on the way no annoying stops have to be made. As this can be a demanding task, the idea could be to improve this route memorising process. There is the possibility to have navigational aiding systems, for example a touch screen mounted to the bicycle (Savino et al., 2021, p. 2). But as this is one approach to support cyclists during mobility with such a tool, another approach or idea would be to enhance the a priori spatial learning process of the route through the display of additional information in the map application. This supplementary information can be given in the form of landmarks, as there is research that through the display of such landmarks the spatial knowledge can be improved (Li, 2020, p. 432). Resulting from that, in this study it has been looked at how local landmarks can influence the a priori spatial learning process and how different symbolisation forms, either as symbols or as real-world pictures, can influence this learning or memorising process. So, the performance which was measured was the number of correct choices taken in comparison with all decisions.

To answer the question of how local landmarks may influence the spatial learning process and how the symbolisation of those can have different influences, a study at the University of Zurich with 39 participants has been conducted. These 39 people have been split up into three different groups, which differed in the fact that they had either visualised the course of the route with additional seven landmarks as symbols ("Symbols" group") or the course of the route with additional seven landmarks as real-world pictures ("Pictures" group) or only the course of the route, without any landmarks displayed ("Without" group). Similar studies also looked more in depth at this symbolisation question and separated groups in a similar manner (Elias and Paelke, 2008, p. 1-24) and (Deakin, 1996, p. 21-36) and (Zhu et al., 2022, p. 669-690). In addition, the participants were associated evenly to those groups based on the result in the spatial ability pre-test, where the Santa Barbara Sense of Direction (SBSOD) test was used. The participants were asked to perform a navigational task in an urban outdoor environment, where they were stationed indoor on a bicycle ergometer and watched a video on a projector where the route was shown via a pre-recorded GoPro video. The task was, that the participants had to memorise a route as good as possible on the computer beforehand, where the different maps were shown with or without the different symbolised landmarks. Afterwards, they had to decide for a direction at different stopping points of the same route as on the map, in the video. In regard of the question on how the symbolisation of landmarks, both as symbols and as pictures, can influence the spatial learning process in comparison with no display of landmarks, no significant difference could be found in the conducted experiment under those specific conditions. Even though no significant data could be found, it appeared that the participants performing with landmarks visualised as symbols performed slightly better when looking over all decisions. However, this result should be treated with caution, as this better performance is rather slight and when only looking at the decisions where landmarks have been visualised, this better achievement cannot be seen anymore. It is rather interesting to see in the data, that the participants in the "Symbols" group and "Pictures" group performed better than the attendees in the "Without" group in the beginning of the route, which changes in the end of the route, where the participants in the "Without" group performed better. This effect can be associated with the concept of cognitive load (Cheng et al., 2018b, p. 3). In more detail, the symbolisation could have led to the fact that the participants which had landmarks visualised could not remember all the landmark information, especially the ones in the end of the route, and therefore performed worse in the finish. In addition to the performance, the participant's decision time and

confidence were also recorded, with a tendency for attendees in the "Symbols" or "Pictures" group to decide more quickly and confidently than participants in the "Without" group. But here too it has to be stated that this was a tendency and the data not significant.

For the question, if there is a difference between symbolised landmarks either as symbols or pictures no significant variation between these two symbolisations used in this experiment could be found. Even though no significant data could be found, it was seen that the participants performing with landmarks visualised as symbols, performed slightly better when looking over all decisions, in comparison with the attendees performing with landmarks visualised as pictures. However, this result should be taken with caution, as the better achievement is only marginal, and if only the decisions where landmarks were visualised are considered, this better performance can no be longer be detected. Interestingly, it could as well be seen, that when looking at the single decisions, the decisions where landmarks have been visualised, the participants in the "Pictures" group performed better in the early landmarks of the route, which changed towards the later landmarks, where the participants in the "Symbols" group and the "Pictures" group performed similarly. Regarding the decision time and confidence of the attendees, between the "Pictures" group and "Symbols" group, it can be stated that the decision time was slightly lower in the "Pictures" group, but the confidence slightly higher in the "Symbols" group.

In summary, although no significant results were found on whether landmarks improve the a priori spatial learning process in the first place, there are some tendencies that presentation as both symbols and pictures may help and that less time for decision-making and higher confidence may result. It was also partially confirmed that the first shown landmarks helped better than the one in the end, relating to the concept of cognitive load. To investigate which landmarks and which symbols helped or contribute most to spatial learning is rather difficult and would be interesting to be part of further studies. It should be kept in mind that a different study design and the changing of certain aspects could have led to different results.

## 6.1 Outlook

This master thesis should serve as a possible direction indicator, that in the topic of landmarks and how this may effect spatial learning, further research should be done to investigate the impact more in depth. Literature already suggest a beneficial effect of landmarks in spatial learning, navigation and orientation (Li, 2020, p. 432) and (Löwen et al., 2019, p. 13) and (Yesiltepe et al., 2021, p. 405). Nevertheless, as the definition of landmarks can be difficult sometimes and therefore also its display, further research could answer certain questions and create clarity (Montello, 2017, p. 193,194). Looking at the above mentioned discussion points and the critics of the conducted study, different aspects would be in need of improvement. A first idea to carry on would be to raise the study participants number to either strengthen the existing results or also to research new findings. Additionally to that, it would be interesting to change the above mentioned parameters of the study and work for instance with different landmarks or in other words, focus on the choosing of the landmarks. Of course, in addition to the choice of landmarks, their symbolisation is also of great importance, and here, as well, thorough research should be done to find out which symbolisations and representations can really be helpful. The field of symbolisation and representation opens up a huge research area of its own, where for example, aspects such as colour blindness or cultural differences in symbolisation should also be looked at in depth. A survey or study focusing only on the selection of landmarks and their symbolisation and representation would therefore make sense. For this, it could also be useful to work with the eye-tracker device to monitor which objects are looked at the most by people. Last but not least a point which have not been mentioned and explored in more depth in the course of this thesis, is the feasibility

and the challenges that would arise. If such an integration of the presentation of local landmarks in a map application is implemented, there are several aspects that need to be considered. On the one hand, there would certainly be major questions regarding the interface and the application itself. On the other hand, issues regarding privacy are also of great importance, since the inclusion of pictures may also show private houses or other private landmarks.

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# Appendix

## Chapter A "E-Mails"

**First information e-mail english**

For my master thesis I am looking for participants for my indoor navigation study. Even though January can be quite busy I would very much appreciate your participation and your help for my master thesis.
If you would like to participate, please sign up in the following Doodle: …
If none of the proposed dates would fit, I am also very happy to arrange a date outside the specified times if you are interested. In addition to singing up in the doodle, please answer shortly to this e-mail so that I can answer you with a more detailed e-mail.
Here are some general details of the study listed:

**Duration**: ca. 45min
**Location**: Y25-J87 (experiment room) / meeting point library of the geographical institute (Y25-K22), UZH Irchel campus (Winterthurerstrasse 190, 8057 Zürich)
**Compensation**: **A sweet surprise** 😉
**Inclusion criteria**:

- Healthy adult (18 – 65 years old), no illness symptoms of any kind;
- 2G (vaccinated, recovered) --> **Covid-Certificate Check**
- Facial mask
- Ability to ride a bicycle
- Basic english knowledge
-

**Exlusion criteria**:

- Good spatial knowledge of the city of Aarau
- History of neurological conditions such as epilepsy or migraine

**Language**: German or English
**Time slots**: 17.01.22 to 4.02.22

**First information e-mail german**

Für meine Masterarbeit bin ich auf der Suche nach Teilnehmenden für meine Indoor-Navigations-Studie. Über deine Teilnahme an der Studie würde ich mich sehr freuen und es würde mir mit meiner Masterarbeit sehr weiterhelfen.
Falls du gerne mitmachen würdest, trage dich bitte im folgenden Doodle ein: …
Wenn keiner der vorgeschlagenen Termine passen würde, können wir bei Interesse auch sehr gerne einen Termin ausserhalb der angegebenen Zeiten abmachen. Zusätzlich zum Doodle wäre ich sehr froh, wenn du mir auf diese E-Mail kurz antworten könntest, damit ich dir noch detaillierte Informationen zusenden kann.
Hier sind die Details der Studie aufgelistet:

**Dauer**: ca. 45min
**Ort**: Y25-J87 (Experiment Raum) / Treffpunkt vor der Bibliothek des Geographischen Instituts (Y25-K22), UZH Irchel Campus (Winterthurerstrasse 190, 8057 Zürich)
**Kompensation**: **Eine süsse Überraschung** 😉
**Inklusionskriterien**:

- Gesunde, erwachsene Person (18 – 65 Jahre), keine Krankheitssymptome jeglicher Art;
- 2G (geimpft, genesen) --> **Covid-Zertifikat Check**
- Mund-Nasen-Schutz
- Fähigkeit Fahrrad zu fahren
- Englischgrundkenntnisse
-

**Ausschlusskriterien:**

- Gute räumliche Kenntnisse der Stadt Aarau
- Neurologische Erkrankungen (z.B. Epilepsie oder Migräne)

**Sprache**: Deutsch oder Englisch
**Termine**: 17.01.22 bis 4.02.22

**Second more detailed e-mail english**

Thank you a lot for signing up for the study of my master thesis. To give you a brief overview in advance about what I am doing, I am shortly explaining the topic to you. In my master thesis I am investigating if the display of landmarks in a navigation app or service can increase the a priori spatial learning process. In addition to that I am researching if different symbolizations of those landmarks (either as symbols or as realistic pictures) have an influence on the a priori spatial learning process.
More detailed information about the experiment and the task will be given to you at the experiment and of course more information about the topic and my thesis if you are interested in.

For your information the declaration of consent is attached to this e-mail, please read it carefully before the experiment.

**Date and time of your experiment:** …
**Procedure of the experiment:** Spatial ability pre-test (at home, more information below), main-study and short questionnaire (at Irchel Campus).
**Location of the experiment:** Y25-J87 (experiment room) / meeting point in front of the library of the Institute of Geography (Y25-K22), UZH Irchel campus (Winterthurerstrasse 190, 8057 Zürich) (please be there 5 min before the actual experiment time)

Things to consider before the experiment (**please read carefully**):

- For the safety of everyone, you must conform to the COVID rules (**2G** vaccinated, recovered) to participate on this study --> Covid-Certificate will be checked.
- Only participants **without** any symptoms of illness are allowed to participate.
- You will have to wear a face mask through the entirety of the study.
- The ventilation is turned on in the room.
- In case you have any questions, feel free to contact me. E-Mail: florian.sturzenegger@uzh.ch, Phone: +41 79 853 43 03.
- Attached is the consent form, please read it before the experiment and if you have questions we can clarify them in person.

**Important: Spatial ability pre-test**
Before your participation on campus I would ask you to fill out this spatial-ability pre-test at home which you can access through the link down below. **Please do this until 1 day before the main study at the latest.** You simply have to fill out the questions in the Google Forms and click on send at the end. The test takes about 5-10 min.

**Second more detailed e-mail german**

Vielen Dank für deine Teilnahme an meiner Masterarbeitsstudie.
Um dir vorab einen kurzen Überblick darüber zu geben, was ich in meiner Arbeit mache, erkläre ich dir kurz das Thema. In meiner Masterarbeit untersuche ich, ob das Anzeigen von Landmarken in einer Navigations-App oder einem Navigationsdienst den räumlichen Lernprozess a priori steigern kann. Darüber hinaus untersuche ich, ob unterschiedliche Symbolisierungen dieser Landmarken (entweder als Symbole oder als realistische Bilder) einen Einfluss auf den a priori räumlichen Lernprozess haben.
Genauere Informationen über das Experiment und die Aufgabenstellung erhältst du beim Experiment und natürlich auch mehr Informationen über das Thema und meine Arbeit, wenn du daran interessiert bist.

Zu deiner Information ist dieser E-Mail die Einverständniserklärung beigefügt. Ich bitte dich diese vor dem Experiment sorgfältig zu lesen.

**Datum und Zeit des Experimentes:** …
**Ablauf des Experiments:** Spatial ability pre-test (zu Hause, Information weiter unten), Hauptstudie und kurzer Fragebogen (am Irchel Campus).
**Ort des Experimentes:** Y25-J87 (Experiment Raum) / Treffpunkt vor der Bibliothek des Geographischen Instituts (Y25-K22), UZH Irchel Campus (Winterthurerstrasse 190, 8057 Zürich) (bitte erscheine 5 min vor Experimentbeginn)

Dinge, die vor dem Experiment zu beachten sind (**bitte sorgfältig lesen**):

- Zur Sicherheit aller musst du die geltenden COVID-Regeln erfüllen (**2G** geimpft, genesen), um an dieser Studie teilnehmen zu können --> Covid-Zertifikat wird kontrolliert.
- Es dürfen nur Teilnehmer **ohne jegliche** Krankheitssymptome teilnehmen.
- Du musst während der gesamten Dauer der Studie eine Gesichtsmaske tragen.
- Die Lüftung im Raum ist eingeschaltet.
- Falls du Fragen hast, kannst du mich sehr gerne kontaktieren. E-Mail: florian.sturzenegger@uzh.ch, Telefon: +41 79 853 43 03.
- Im Anhang findest du die Einverständniserklärung, bitte lies Sie diese vor dem Experiment durch und falls du Fragen hast, können wir diese vor Ort beim Experiment klären.

**Wichtig: "Spatial ability pre-test"**

Bevor du an der Hauptstudie vor Ort teilnimmst, möchte ich dich bitten, diesen Test zum räumlichen Vorstellungsvermögen zu Hause auszufüllen, den du über den untenstehenden Link aufrufen kannst. **Bitte tu dies bis spätestens 1 Tag vor der Hauptstudie.** Fülle hierzu einfach die Fragen im Google Forms aus und klicke am Ende auf "Senden". Der Test dauert ungefähr 5-10 min.

## Chapter B "Declaration of Consent" (German and English) (GIUZ Template)

University of Zurich[UZH]

### Declaration of consent

Dear study participant

You are invited to participate in a study conducted by Florian Sturzenegger (+41 79 853 43 03, florian.sturzenegger@uzh.ch) as part of his master's thesis "Representation of local landmarks in bicycle navigation apps and its effect on learning planned routes" at the Department of Geography, University of Zurich.

**Purpose of the study**
The purpose of this study is to investigate how the representation of local landmarks in map applications can improve the learning and remembering of a particular route. It will be investigated whether a different representation of landmarks improves this learning and remembering process and whether these types of representation are differentially helpful.

**General Information**
The main study will take place at the Institute of Geography of the University of Zurich (Campus Irchel) in the CAVE lab (Y25-J84) and will last about 45 minutes.

**Procedure of the study**
If you decide to take part in the study, you will be asked to complete a "Spatial Ability Test" at home (online via Google Forms) and provide some information about yourself.
At the main on-site study, you will perform a navigation task where you will virtually travel a route in front of a screen and have to make decisions along the way. More detailed information about this task and how to navigate the virtual environment will be given during the study. After completing the navigation task, you will be asked to answer some questions about the main study. The total duration of the study is approximately 45 minutes.

**Voluntary participation**
Your participation in this study is voluntary. You can withdraw your consent to participate in this study at any time without giving reasons. You can also ask questions about the study at any time.

**Inclusion and exclusion criteria**
Any healthy adult of legal age who meets the following inclusion criteria and exclusion criteria may participate in this experiment. An age limit is set only to ensure that volunteers can easily use the experimental methods required for the aim of the study. In addition, the exclusion criteria listed below ensure that our statements are derived from healthy subjects.

- **Inclusion criteria**
- healthy
- 18-65 years old
- Ability to ride a bicycle
- BAG COVID requirements (vaccinated or recovered (2G))

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University of Zurich[UZH]

- No COVID related symptoms (e.g., Fever, cough, sore throat etc.)
- Wearing of a hygienic mask

- **Exclusion criteria**
- Good spatial knowledge of the city of Aarau
- History of neurological conditions such as epilepsy or migraine.

**Obligations of the study participant**
- You are expected to follow the instructions of the experimenter carefully.
- Uncomfortable experiences during the experiments must be reported immediately.
- Inform the experimenters in case of changes in health status that could affect your inclusion in the study.

**Advantages for the study participant**
This study offers no direct benefits to the study participant.

**Risks for the study participant**
Prolonged viewing of large screen projections may cause dizziness similar to seasickness. We will provide you with breaks and water to reduce the likelihood of these symptoms occurring.

Epilepsy patients or people with a known family history of epilepsy are excluded from the experiment. People with no known history of epilepsy may also experience a sudden onset of illness due to the light patterns of the projection. If any of the following symptoms occur while viewing the projection, do not delay and inform the experimenter, who will stop the experiment:
- Eye or muscle twitching, muscle cramps
- Severe dizziness, nausea

**Changes to the information provided**
Any changes to the study that may affect the safety of your participation or your privacy will be communicated to you in writing.

**Confidentiality of data**
This study involves the collection of your personal data. All data will be encrypted and anonymized by replacing your name with a code. In addition, your name will not be used in the work. All data collected will be kept encrypted and stored on secure media.

The personal data provided here will be stored for a period of 10 years due to a legal obligation. A local ethics committee may review the information during this period. All information is stored in a locked laboratory room and on a highly secure server at the Institute of Geography of the University of Zurich. Your data can be published in anonymized form in the scientific community.

**Cost for the study participant**
The study does not incur any direct costs for the study participant.

University of Zurich[UZH]

**Compensation**
There is no financial compensation for participating.

**Termination of participation**
Your participation in the study will be discontinued,

- If you are unable to understand / follow instructions from the investigator.
- If changes occur in your self-reported health condition that apply to the exclusion criteria.
- If you withdraw from participation in the study. If you withdraw your participation, your records will be deleted.

**Damages**
This is a minimal risk study, and we are not insured for any harm that may occur to you during the study. However, if your participation in the study is associated with any physical or mental distress, please contact us immediately. We will assist you as best we can and provide clinical counseling as appropriate.

**Contact persons**
If any uncertainties, concerns, or emergencies arise during or after the study, you may contact any of the following persons: Florian Sturzenegger (+41 79 853 43 03, florian.sturzenegger@uzh.ch)

**Declaration of consent**

1) I was given enough time to read the information sheet and all my questions about this experiment were answered satisfactorily.
2) In a case where I am unable to read this document or provide written consent, I acknowledge that I have received the information verbally.
3) I understand the requirements of the experiment and agree to participate in this study.
4) My participation is voluntary, and I have not been forced to participate in this study in any way.
5) I acknowledge that I may withdraw my consent to participate in the study at any time.
6) I agree that my data may be used in anonymized form for research purposes only and may be published in professional publications.
7) I understand that a local ethics committee may review my personal information to verify activities of this research study.
8) I understand that my personal information will be kept confidential under all circumstances.
9) I understand that the study directors, in the interest of the study, may terminate my participation at any time.
10) I understand that I must follow the instructions of the instructor and comply with the requirements of the instruction sheet.


| Place, Date | Signature of the **participant** |
|---|---|
| | |

☐ The participant has received the information contained on this form verbally upon request.

**Experimenter's Statement:** I certify that I have explained the study and the use of the study participant's data. I have encouraged the study participant to seek an explanation of the experiment and his/her rights. If there are any changes that affect the study participant during the course of the experiment, I will inform them immediately and ask for their consent. I certify that this study meets all legal obligations and complies with national rules and international guidelines for human experimentation.

| Place, Date | Signature of the **experimenter** |
|---|---|
| | |

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## Einverständniserklärung

Sehr geehrte Studienteilnehmerin, sehr geehrter Studienteilnehmer

Sie sind eingeladen, an einer Studie teilzunehmen, die von Florian Sturzenegger (+41 79 853 43 03, florian.sturzenegger@uzh.ch) im Rahmen seiner Masterarbeit „Representation of local landmarks in bicycle navigation apps and its effect on learning planned routes“ am Geographischen Institut der Universität Zürich durchgeführt wird.

**Zweck der Studie**
Der Zweck dieser Studie ist es zu untersuchen, wie die Darstellung von lokalen Landmarken in Kartenapplikationen das Lernen und Erinnern einer bestimmten Route verbessern kann. Es wird hierbei untersucht, ob eine unterschiedliche Darstellung der Landmarken diesen Lern- und Erinnerungsprozess verbessert und ob diese Darstellungsarten unterschiedlich hilfreich sind.

**Allgemeine Information**
Die Hauptstudie findet im Geographischen Institut der Universität Zürich (Campus Irchel) im CAVE Labor (Y25-J84) statt und wird ca. 45 Minuten dauern.

**Studienablauf**
Wenn Sie sich für die Teilnahme an der Studie entscheiden, werden Sie gebeten vorab einen „Spatial Ability Test“ zu Hause (online via Google Forms) auszufüllen und einige Angaben zu ihrer Person zu machen.
Bei der Hauptstudie vor Ort werden sie eine Navigationsaufgabe durchführen, bei der Sie vor einer Leinwand eine Route virtuell abfahren werden und dabei Entscheidungen treffen müssen. Detailliertere Informationen zu dieser Aufgabe und zur Navigation in der virtuellen Umgebung werden im Laufe der Studie gegeben. Nach Abschluss der Navigationsaufgabe werden Sie aufgefordert, einige Fragen zur Hauptstudie zu beantworten. Die Gesamtdauer der Studie beträgt ca. 45 Minuten.

**Freiwillige Teilnahme**
Ihre Teilnahme an dieser Studie ist freiwillig. Sie können Ihre Einwilligung zur Teilnahme an dieser Studie jederzeit ohne Angabe von Gründen widerrufen. Sie können auch jederzeit Fragen zu der Studie stellen.

**Inklusions- und Exklusionskriterien**
Jeder gesunde volljährige Erwachsene, der die folgenden Inklusionskriterien und Exklusionskriterien erfüllt, kann an diesem Experiment teilnehmen. Eine Altersgrenze wird nur festgelegt, um sicherzustellen, dass die Freiwilligen die experimentellen Methoden, die für das Ziel der Studie erforderlich sind, problemlos anwenden können. Darüber hinaus stellen die unten aufgeführten Ausschlusskriterien sicher, dass unsere Aussagen von gesunden Versuchspersonen abgeleitet werden.

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- **Inklusionskriterien**
- gesund
- 18-65 Jahre alt
- Fähigkeit, Fahrrad zu fahren
- BAG COVID Anforderungen (geimpft oder genesen (2G))
- Keine COVID-Krankheitssymptome (z.B. Fieber, Husten, Halsschmerzen etc.)
- Tragen einer Hygiene-/Gesichtsmaske

- **Exklusionskriterien**
- Gute räumliche Kenntnisse der Stadt Aarau
- Vorgeschichte neurologischer Erkrankungen wie z.B. Epilepsie oder Migräne

**Verpflichtungen des/der Studienteilnehmer/-in**

- Es wird erwartet, dass Sie die Anweisungen des Versuchsleiters sorgfältig beachten.
- Unbequeme Erfahrungen während der Experimente sind sofort mitzuteilen.
- Informieren Sie die Experimentatoren im Falle von Veränderungen des Gesundheitszustandes, die sich auf Ihre Aufnahme in die Studie auswirken könnten.

**Vorteile für den/die Studienteilnehmer/-in**

Diese Studie bietet keine direkten Vorteile für den Studienteilnehmenden.

**Risiken für den/die Studienteilnehmer/-in**

Längeres Betrachten von Großbildprojektionen kann zu Schwindelgefühl führen, die einer Seekrankheit ähneln. Wir werden Sie mit Pausen und Wasser versorgen, um die Wahrscheinlichkeit des Auftretens dieser Symptome zu verringern.

Epilepsie-Patienten oder Menschen, bei denen in der Familie Fälle von Epilepsie bekannt sind, sind von dem Versuch ausgeschlossen. Bei Menschen, bei denen keine Epilepsie bekannt ist, kann es ebenfalls aufgrund der Lichtmuster der Projektion zu einem plötzlichen Krankheitsbild kommen. Falls beim Betrachten der Projektion eines der folgenden Symptome auftritt, zögern Sie nicht lange und informieren Sie den Versuchsleiter, der den Versuch abbrechen wird:

- Augen- oder Muskelzucken, Muskelkrämpfe
- Starker Schwindel, Übelkeit

**Änderungen der angegebenen Informationen**

Alle Änderungen der Studie, die die Sicherheit Ihrer Teilnahme oder Ihre Privatsphäre beeinträchtigen können, werden Ihnen schriftlich mitgeteilt.

**Vertraulichkeit der Daten**

Diese Studie beinhaltet die Erfassung Ihrer persönlichen Daten. Alle Daten werden durch das Ersetzen Ihres Namens mit einem Code verschlüsselt und anonymisiert. Darüber hinaus wird Ihr Name nicht in der Arbeit verwendet. Alle gesammelten Daten werden verschlüsselt aufbewahrt und auf sicheren Datenträgern gespeichert. Ihre Daten können in anonymisierter Form in der wissenschaftlichen Community publiziert werden.

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Die hier zur Verfügung gestellten personenbezogenen Daten werden aufgrund einer gesetzlichen Verpflichtung für einen Zeitraum von 10 Jahren gespeichert. Eine lokale Ethikkommission kann die Informationen in diesem Zeitraum prüfen. Alle Informationen werden in einem abgeschlossenen Laborraum sowie auf einem hochsicheren Server am Geographischen Institut der Universität Zürich gespeichert.

**Kosten für den/die Studienteilnehmer/-in**
Die Studie verursacht keine direkten Kosten für den Studienteilnehmenden.

**Entschädigung**
Für die Teilnahme gibt es keine finanzielle Entschädigung.

**Abbruch der Teilnahme**
Ihre Teilnahme an der Studie wird abgebrochen,

- wenn Sie nicht in der Lage sind, Anweisungen des Versuchsleiters zu verstehen / zu befolgen.
- wenn Änderungen des selbst gemeldeten Gesundheitszustandes auftreten, die auf die Ausschlusskriterien zutreffen.
- wenn Sie die Teilnahme an der Studie widerrufen. Sollten Sie Ihre Teilnahme zurückziehen, werden Ihre Aufzeichnungen gelöscht.

**Schäden**
Dies ist eine Studie mit minimalem Risiko und wir sind nicht für Schäden versichert, die Ihnen während der Studie entstehen können. Wenn Ihre Teilnahme an der Studie jedoch mit einer körperlichen oder geistigen Belastung assoziiert sein sollte, setzen Sie sich bitte umgehend mit uns in Verbindung. Wir werden Ihnen so gut wie möglich helfen und Ihnen gegebenenfalls eine klinische Beratung zukommen lassen.

**Kontaktpersonen**
Wenn während oder nach der Studie Unklarheiten, Beunruhigungen oder Notfälle auftreten sollten, können Sie sich an eine der folgenden Personen wenden:

- Florian Sturzenegger (+41 79 853 43 03, florian.sturzenegger@uzh.ch)

**EINVERSTÄNDNISERKLÄRUNG**

1) Mir wurde genügend Zeit gegeben, das Informationsblatt zu lesen, und alle meine Fragen zu diesem Experiment wurden zufriedenstellend beantwortet.
2) In einem Fall, in dem ich nicht in der Lage bin, dieses Dokument zu lesen oder eine schriftliche Einwilligung zu erteilen, bestätige ich, dass ich die Informationen mündlich erhalten habe.
3) Ich habe die Anforderungen des Experiments verstanden und stimme zu, an dieser Studie teilzunehmen.
4) Meine Teilnahme ist freiwillig und ich wurde in keinem Falle gezwungen, an dieser Studie teilzunehmen.

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5) Ich nehme zur Kenntnis, dass ich meine Einwilligung zur Teilnahme an der Studie jederzeit widerrufen kann.
6) Ich bin damit einverstanden, dass meine Daten in anonymisierter Form nur für Forschungszwecke verwendet werden und in Fachpublikationen veröffentlicht werden dürfen.
7) Ich nehme zur Kenntnis, dass eine lokale Ethikkommission meine persönlichen Daten prüfen kann, um Aktivitäten dieser Forschungsstudie zu überprüfen.
8) Ich verstehe, dass meine persönlichen Daten unter allen Umständen vertraulich behandelt werden.
9) Ich nehme zur Kenntnis, dass die Studienleiter, im Interesse der Studie, meine Teilnahme jederzeit kündigen können.
10) Ich verstehe, dass ich mich an die Anweisungen des Versuchsleiters halten und die Anforderungen des Merkblattes erfüllen muss.

| Ort, Datum | Unterschrift **des/der Studienteilnehmer/-in** |
|---|---|
| | |

☐ Die auf diesem Formular enthaltenen Informationen hat der Teilnehmer / die Teilnehmerin auf Anfrage mündlich erhalten.

**Erklärung des Versuchsleiters:** Ich bestätige, dass ich die Studie sowie die Verwendung der Daten des/der Studienteilnehmers/-in erklärt habe. Ich habe den/die Studienteilnehmer/-in ermutigt, sich um eine Erklärung des Experiments und seiner Rechte zu bemühen. Sollten sich im Laufe des Versuchs Änderungen ergeben, die den/die Studienteilnehmer/-in betreffen, werde ich ihn unverzüglich informieren und um Zustimmung bitten. Ich bestätige, dass diese Studie alle gesetzlichen Verpflichtungen erfüllt und mit den nationalen Regeln und internationalen Richtlinien für Humanexperimente übereinstimmt.

| Ort, Datum | Unterschrift des **Versuchsleiters** |
|---|---|
| | |

## Chapter C "Procedure Sheet for Study Conductor" (German and English)

# Procedure of the main study

## 1. Acquiring the participants

*Send an e-mail with a request in participating in the study (hidden Doodle).*

| | |
|---|---|
| Documents | **Doodle** |
| Material | - |

## 2. Information and pre-test

*If the participant inscribes for the study a more detailed e-mail is sent to them with the declaration of consent and the information of the pre-test which they should do until 3 days before the main study.*

| | |
|---|---|
| Documents | **Google Forms with Pre-Test** |
| Material | **Declaration of consent** |

## 3. Meeting and walking to the lab room

*Participant and study conductor meeting in front of the library of the institute of geography.*

**Time: 3 min**

What to say

- Welcoming and thank you
- Checking Covid-Certificate (2G), mask must be worn throughout the entire study
- Say that everything related to the experiment is strictly confidential and will treated as so

*Participant and study conductor walking together to the lab room and participant installing (jacket off etc.).*

**Time: 3 min**

What to say

- Where they can put their clothes and stuff
- Plus hand disinfection (me and participants)
- Sit down at the table

## 4. Entry to of the study

*Participant entering the study → information about the study at the table together.*

**Time: 7 min**

| | |
|---|---|
| Documents | **Declaration of consent, Instruction sheet for participants** |
| Material | **Laptop and Copies** |

What to say

- Read the "Declaration of consent" carefully and please give date and signature
- Mask must be worn throughout the entire study

1

- Experiment can be stopped at any time without giving a reason
- Explanation of the procedure of the study with the instruction sheet for the participants

## 5. Map reading/remembering phase

*Participant sitting at the desk with laptop/computer.*

**Time: 5 min (2 min)**

| Documents | **Instruction sheet for participants** |
|---|---|
| Material | **Laptop/Computer with map** |

What to say

- Content of the instruction sheet
- Only for picture group: Pictures are landmarks seen from the front
- For picture and symbol group → important to say that video is not only stopped at points where the landmark was shown (actually at a lot of points it is stopped and decision is needed)
- No changing of direction in the map possible (make short introduction with the city map not used)
- Time is 2 min, after that changing of place
- Video will also be stopped at points where there is no landmark visualized and there also a decision is needed
- Explain start and ending with the flags
- Clear any questions
- Maybe do small introduction of the functions with a test map

## 6. "Navigation" phase

*Participant changes from the desk to sitting on the ergometer and facing the screen.*

**Time: 15 min - 20 min**

| Documents | **none** |
|---|---|
| Material | **Ergometer, Laptop with Beamer** |

What to say

- Video is played and stops at certain decision points, participants have to say, which direction (A, B or C) it continuous (doesn't matter if correct or incorrect (not a test)) and how confident they are in decision (categories information sheet) (give them sheet for on the ergometer)
- Study conductor has to stop the time in the experiment (when video is stopped until decision) and write down if decision correct or incorrect and how confident they are
- Ask how they feel in between and how they are doing (2x)

## 7. Questionnaire

*Participant sitting at the desk and facing the screen.*

**Time: 5 min**

| | |
|---|---|
| Documents | **Google Forms Questionnaire** |
| Material | **Laptop/Computer/Stop watch?** |

What to say

- Some questions regarding the study
- Fill out based on experience in the study

## 8. Debriefing

*Participant leaving the study → debriefing.*

**Time: 2 min**

| | |
|---|---|
| Documents | **none** |
| Material | **none** |

What to say

- Thank you!
- Clear last questions
- Send you a scan from the declaration of consent.

## 9. Cleaning

*Disinfection lab and laptop (+material), computer (+material) and ergometer.*

**Time: 5 min**

| | |
|---|---|
| Documents | **none** |
| Material | **Disinfection towels and hand-sanitizer** |

3

## Chapter D "Instruction Sheet for Participants" (German and English) (GIUZ Template)

University of Zurich[UZH]

Master Thesis Florian Sturzenegger
"Representation of local landmarks in bicycle navigation apps and its effect on learning planned routes"

### Information sheet

**Procedure and information**

*„Spatial-Ability-Test"*

The test consists of a questionnaire that allows me to assess your spatial abilities and your sense of orientation. This assessment will be taken into account at the end of the evaluation of the data in order to correctly classify the data obtained. It is important to note that it is not your performance that is being measured, but rather your self-assessment, and that you should answer the questions as truthfully as possible.

*Main study*

In the main study you will be able to look at a specific bicycle route on an interactive map on the computer and you will be asked to memorize the route and the junctions as well as possible. You are not allowed to use any other tools for this purpose, except for the functions available in the interactive map.
The map shows either the exact course of the route or the exact course of the route with selected landmarks on the route, which are shown as symbols or real pictures.
After that, you will change places and sit on an ergometer in front of a screen where you will see the same route in real life from the head perspective of a cyclist as a video. Try to constantly move the pedals to simulate riding a bike (but no heavy exertion needed). At certain decision points, the video is paused, and the possible branching options are indicated in the video with arrows. Your task is then to tell the right turn (A, B or C) using the route you have memorized. Important, the video will stop at various turn-offs along the entire route, including those where there are no landmarks. This means that you should remember all the direction changes.
When choosing the branch (A, B or C) it is important that you try to make the right choice if possible. The speed at which you give the answer is secondary. In addition to indicating the branch (A, B or C), you should indicate how sure you are about the decision.
For this purpose, please use the following categorization:

| Unsure | Neutral | Sure |
|---|---|---|

Page 1/2

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**Important points regarding the content of the video:**

- The recorded video was shot with a GoPro on the helmet to create as realistic a driving situation as possible. It is important to note here that the driving path shown, and the camera movements do not indicate which direction or turn is chosen. The driving path had to follow the laws of road traffic and the movements of the camera followed due to movements of the head to observe the environment for driving.

Examples:

1. In most cases, people ride on the right side of the road, because bike lanes are usually on the right side of the road. However, this would not mean that a right turn is always made.
2. At intersections, looking over the shoulder on the left was not meant to mean turning left, but simply a general observation before turning in any direction.
3. Labels on the ground on the road do not indicate where to turn at the next intersection.

*Short Questionnaire*

After completing the main study, you will be asked to fill out a short questionnaire on the computer on site. This involves general questions about the completed navigation study.

Thanks a lot for participating in the study!

University of Zurich[UZH]

Master Thesis Florian Sturzenegger
"Representation of local landmarks in bicycle navigation apps and its effect on learning planned routes"

## Informationsblatt

**Ablauf und Informationen**

*„Spatial-Ability-Test"*

Der Test besteht aus einem Fragebogen, mithilfe dessen wir Ihre räumlichen Fähigkeiten und Ihren Orientierungssinn einschätzen können. Diese Einschätzung wird am Ende bei der Auswertung der Daten berücksichtigt, um die erhaltenen Daten richtig einordnen zu können. Wichtig hierbei anzumerken ist, dass nicht ihre Leistung gemessen wird, sondern es sich um eine Selbsteinschätzung handelt, und dass Sie die Fragen so wahrheitsgetreu wie möglich beantworten sollen.

*Hauptstudie*

In der Hauptstudie werden Sie am Computer auf einer interaktiven Karte eine bestimmte Fahrradroute anschauen können und sie werden gebeten, sich den Routenverlauf und die Abzweigungen so gut wie möglich zu merken. Dazu dürfen Sie keine weiteren Hilfsmittel benützen, ausser der Funktionen, die in der interaktiven Karte vorhanden sind.
Dargestellt in der Karte sind entweder nur der exakte Routenverlauf oder der exakte Routenverlauf mit ausgewählten Landmarken auf der Route, die als Symbole oder Echtbilder dargestellt sind.
Danach werden sie den Platz wechseln und auf einem Ergometer vor einer Leinwand sitzen und dort dieselbe Route in Natura aus der Kopfperspektive einer Fahrradfahrerin/eines Fahrradfahrers als Video sehen. Versuchen Sie ständig die Pedale zu bewegen, um so das Fahrradfahren zu simulieren (aber keine starke Belastung nötig). An bestimmten Entscheidungspunkten wird das Video angehalten und die möglichen Abzweigungsmöglichkeiten werden im Video mit Pfeilen angezeigt. Ihre Aufgabe ist es dann mithilfe der von Ihnen eingeprägten Route die richtige Abzweigung mitzuteilen (A, B oder C). Wichtig, das Video wird an verschiedenen Abbiegestellen auf der ganzen Route angehalten, also auch an solchen, wo es keine Landmarken gibt. Dies bedeutet, dass Sie sich möglichst alle Richtungswechsel merken.
Bei der Auswahl der Abzweigung (A, B oder C) ist es wichtig, dass sie versuchen, möglichst die Richtige Wahl zu treffen. Die Geschwindigkeit, wie schnell Sie die Antwort geben ist sekundär.
Zusätzlich zur Angabe der Abzweigung (A, B oder C) sollen sie mitteilen, wie sicher Sie sich mit der Entscheidung sind.
Hierfür verwenden Sie bitte folgende Kategorisierung:

| Unsicher | Neutral | Sicher |
|---|---|---|

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**Wichtige Punkte inhaltlich zu Video:**

- Das aufgenommene Video wurde mit einer GoPro auf dem Helm aufgenommen, um eine möglichst realistische Fahrsituation zu schaffen. Wichtig anzumerken hierbei ist, dass der gezeigte Fahrweg und die Kamerabewegungen nicht darauf schliessen lassen, welche Richtung oder Abzweigung gewählt wird. Der Fahrweg musste den Gesetzen des Strassenverkehres folgen und die Bewegungen der Kamera folgten aufgrund von Bewegungen des Kopfes, um die Umgebung für die Fahrt zu beobachten.

Beispiele:

1. In den meisten Fällen wird rechts auf der Strasse gefahren, da die Fahrradwege in den meisten Fällen rechts auf der Strasse verlaufen. Dies würde aber nicht heissen, dass immer rechts abgebogen wird.
2. Bei Kreuzungen wurde links über die Schulter geschaut, was aber nicht heissen soll, dass nach links abgebogen wird, sondern einfach ein generelles Beobachten vor dem Abbiegen in jede Richtung.
3. Beschriftungen am Boden auf der Strasse deuten nicht darauf, wo an der nächsten Kreuzung abgebogen wird.

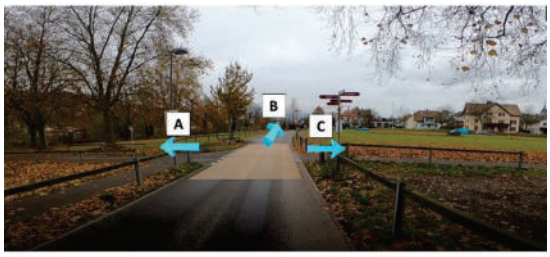
*Kurzer Fragebogen*

Nach Beenden der Hauptstudie sind Sie gebeten noch einen kurzen Fragebogen am Computer vor Ort auszufüllen. Dabei dreht es sich um allgemeine Fragen zur absolvierten Navigationsstudie.

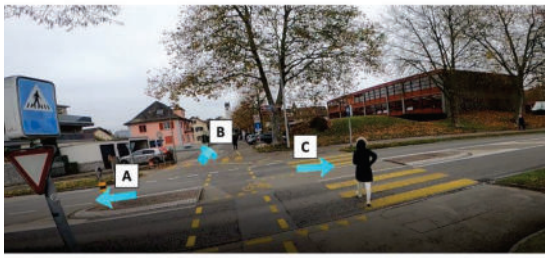
Vielen Dank für das Mitmachen in der Studie!

**Chapter E "Stopping Situations in the Video" (Final Route Aarau)**

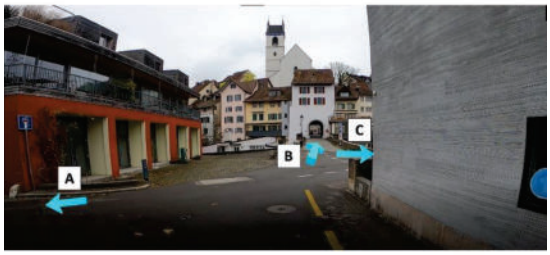
Decision 1



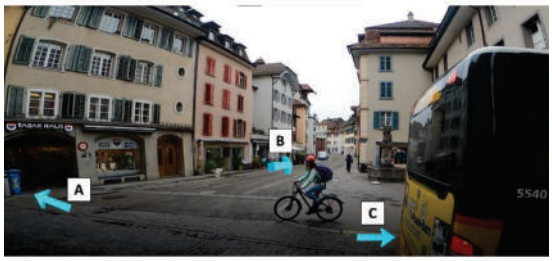

Decision 2



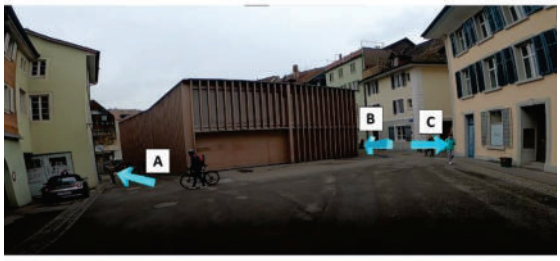

Decision 3
(Landmark 1)




Decision 4
(Landmark 2)



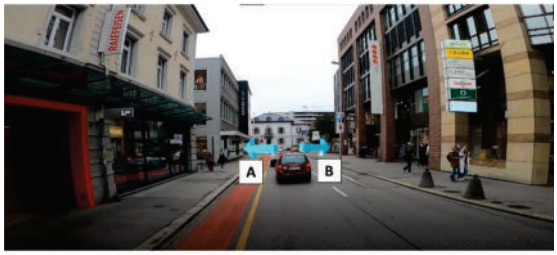

Decision 5
(Landmark 3)



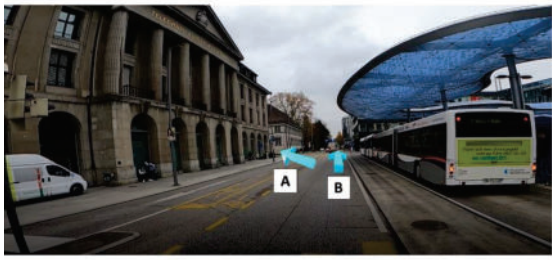

1

Decision 6

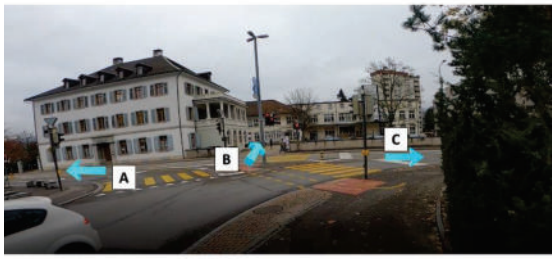

Decision 7




Decision 8
(Landmark 4)



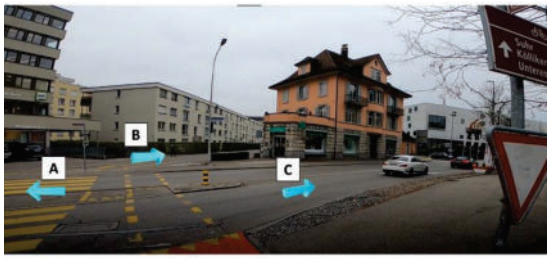

Decision 9
(Landmark 5)



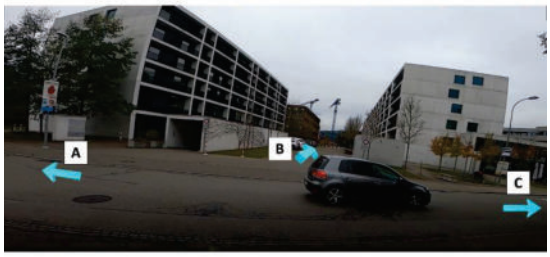

Decision 10
(Landmark 6)


2

Decision 11
(Landmark 7)




Decision 12




3

## Chapter F "Post-study Questionnaire" (via Google Forms)



### Post-study questionnaire

Thanks for participating in the study. To finish the study please fill in this short questionnaire.

* Erforderlich

1. 1. Please state whether the landmarks were shown as abstract symbols or as pictures on your map? *

   *Markieren Sie nur ein Oval.*

   - ◯ Pictures
   - ◯ Symbols
   - ◯ none

2. **This question is only for participants who had landmarks visualized either as symbols or as pictures in the map**. 2. How much did the display and the design of the visualized landmarks in the map help you in recognising the actual landmarks in the video [1 = not at all, 5 = very much]?

   *Markieren Sie nur ein Oval.*

| | 1 | 2 | 3 | 4 | 5 | |
|---|---|---|---|---|---|---|
| not at all | ◯ | ◯ | ◯ | ◯ | ◯ | very much |

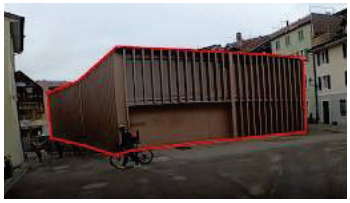
3. 3. Which landmarks in the video did you find most prominent? *

Post-study questionnaire

*Wählen Sie alle zutreffenden Antworten aus.*

☐ Landmark 1

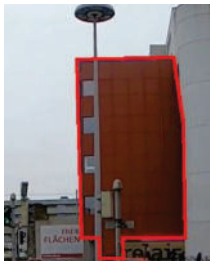
☐ Landmark 2



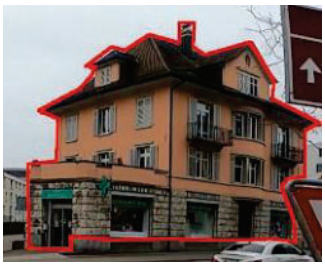
☐ Landmark 3

☐ Landmark 4

☐ Landmark 5



☐ Landmark 6



☐ Landmark 7

2/7

Post-study questionnaire

4. **This question is only for participants who had landmarks visualized either as symbols or as pictures in the map**. 4. Did the display of landmarks in the map help you in increasing your a priori spatial learning process of the route (i.e., remember the turns to take) [1 = not at all, 5 = very much]?

*Markieren Sie nur ein Oval.*

| | 1 | 2 | 3 | 4 | 5 | |
|---|---|---|---|---|---|---|
| not at all | ⬭ | ⬭ | ⬭ | ⬭ | ⬭ | very much |

Post-study questionnaire

5. **This question is only for participants who had landmarks visualized either as symbols or as pictures in the map**. 5. Which of the landmarks helped you the most for solving the navigation task?

*Wählen Sie alle zutreffenden Antworten aus.*

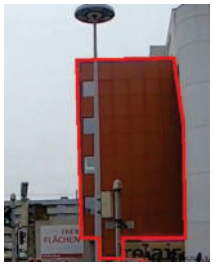
☐ Landmark 1

☐ Landmark 2

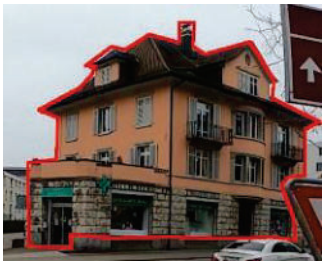
☐ Landmark 3

☐ Landmark 4

☐ Landmark 5



☐ Landmark 6



☐ Landmark 7

4/7

Post-study questionnaire

6. **This question is only for participants who had landmarks visualized as symbols in the map**. 6. How accurate did the symbols represent the landmarks shown in reality [1 = not at all, 5 = very much]?

*Markieren Sie nur ein Oval.*

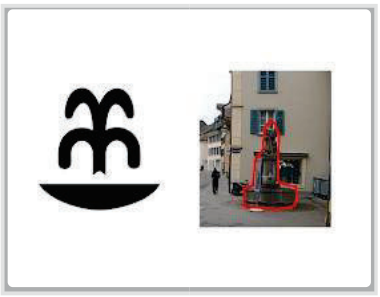
| | 1 | 2 | 3 | 4 | 5 | |
|---|---|---|---|---|---|---|
| not at all | ◯ | ◯ | ◯ | ◯ | ◯ | very much |

Post-study questionnaire

7. **This question is only for participants who had landmarks visualized as symbols in the map**. 7. Which symbols did the reality represent best?

*Wählen Sie alle zutreffenden Antworten aus.*

☐ Option 1



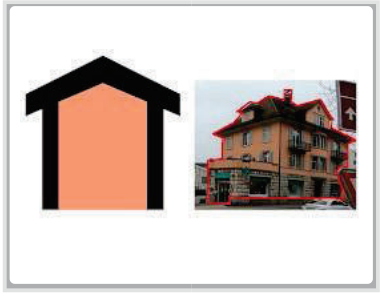
☐ Option 2

☐ Option 3

☐ Option 4

☐ Option 5

☐ Option 6



☐ Option 7

6/7

Post-study questionnaire

8. 8. In a routing app (such as Google Maps), would you find it useful if landmarks were displayed as symbols or images [1 = not at all, 5 = very much]? * *Markieren Sie nur ein Oval.*

| | 1 | 2 | 3 | 4 | 5 | |
|---|---|---|---|---|---|---|
| not at all | ◯ | ◯ | ◯ | ◯ | ◯ | very much |

9. 9. Do you want to add something regarding the navigation task (i.e. have you lost the orientation at some point or influenced by something (i.e. dizziness)

7/7

## Chapter G "Post-study Questionnaire - Answers for Last Question"

**Question 9: Do you want to add something regarding the navigation task (i.e. have you lost the orientation at some point or influenced by something (i.e. dizziness)?**

Answer 1
- Rosa Haus: habe aufgrund der Karte eine Kirche erwartet und bin deshalb nicht rechts abgebogen beim Würfel
- Busstation sehr auffällig und hilfreich
- Einfahrt in die Altstadt v.a. wegen der gesamten ersten Häuserzeile auffällig, nicht nur wegen dem weiss dargestellten Haus.
- Ganz am Schluss schwierig (Route von vorne her gemerkt)
- Gleise hilfreich für Orientierung.
- Beim Brunnen hat das Symbol tatsächlich geholfen. Ich wäre auch ohne Symbol geradeaus gefahren, aber der Brunnen (nur mit Symbol bemerkt) gab Sicherheit.

Answer 2
It was more difficult to orient myself within the old city district. Furthermore, after giving a wrong answer, the orientation was lost. What helped me guessing, and may influence the results, were the bicycle signs on the ground. The architecture had the highest influence for me (blue modern structure/bus station, big old house at this big street crossing). I thought the "Törli" was the church.

Answer 3
In the beginning, it was hard to get used to the video and I felt a bit dizzy. Pausing the cycling helped to get used to it. It was a bit hard to orient myself in the beginning due to the dizziness and I also usually orient myself according to green places (I tried to remember, that for the first turn I needed to go right once I reached the green patch of grass on the map, but in reality, it grass was already around us). I found it very hard to spot the color of the houses, except for the white house since it is so prominent. More than once, I confused the houses, because there was another house of similar color nearby. I also thought I had spotted the fountain, but it turns out the fountain I thought to have spotted was the wrong one coming later on the route. I didn't spot the original fountain, maybe because it was a bit hidden in the corner and I would have expected a fountain more visible. As for the second fountain, I didn't really know where to go at the intersection, but since I remembered that I need to choose the straight path from the fountain, I went with this option. However, it was the wrong fountain, so I might just have been lucky. Easy to spot were the bus station, but not because of the busses but the strange looking roof of the station, that caught my eye when I observed the map. Additionally helpful were the train tracks because I remembered that I need to cross them. Personally, I don't think that houses make for helpful landmarks with a few exceptions. I think parks of patches of grass/green might be better landmarks (because that's the I usually try to orient myself).

Answer 4
Sometimes I was influenced by the direction to which the cyclist was looking. But I think it is impossible to prevent that. It was difficult to keep orientation after a certain driving time, with only having seen the route without any landmarks that could enhance one's awareness of where on the route you are.

1

Answer 5
Die Distanzabschätzung war ziemlich schwierig wie weit man schon gefahren ist im Vergleich zu der eingeprägten Distanz auf der Karte.

Answer 6
hard to estimate distances until you have to go right for instance. official street signs (bike route) help a lot.

Answer 7
Ich verlor die Orientierung und fand sie wieder beim Zug Gleis

Answer 8
Ich habe den Brunnen zu spät gesehen, ansonsten hätte ich die Richtung gewusst.

Answer 9
Die Karte wurde meinerseits etwas anders gelesen

Answer 10
Der Bahnhof hat mir geholfen, zu verstehen an welchem Punkt der Route ich etwa war. Die grosse Kreuzung vor der Gleisunterführung war ebenfalls wichtig für die Orientierung.

Answer 11
Ich habe mir noch andere Dinge gemerkt, die ich auf der Karte gesehen habe, wie zum Beispiel, die Unterführung der Zuggleise. Oder auch habe ich versucht die Distanzen abzuschätzen, was mich schlussendlich nur verwirrt hat. Einige der Gebäude habe ich gar nicht gesehen, also das Rote Gebäude ist mir nie aufgefallen.

Answer 12
I felt a bit of dizziness, but it didn't influence my decisions

Answer 13
Die Landmarker waren insbesondere am Anfang der Route sehr hilfreich. Die Orientierung konnte dadurch schneller hergestellt werden. Ab Landmarker 3 bis 4 wurde es schwierig auch prominente Bilder ins Gedächtnis zurückzurufen.

Answer 14
Ich merke mir die Abzweiger (Kreuzungen) an welcher ich abbiegen muss, ansonsten fahre ich immer gerade aus. Gut merkbar für mich sind auch die dicke der Strasse (Haupt-, Nebenstarasse und Fahrradwege). Die unbebauten Flächen dienen mir auch als Anhaltspunkte.

Answer 15
Die Bahngeleise fielen mir auf, wusste aber nicht in welche Richtung. Orientierung/Konzentration nach der Hälfte des Weges schwieriger....

2

Answer 16
Am Schluss nur noch spontan geurteilt mehr auf rechts / links (eher am Schluss auf Route anstelle auf Landmarken)

Answer 17
Meine Strategie:
- Beim Einprägen der Route:
- Kurvenfolge --> z.B. fast nie links abbiegen (evtl. Limitation)
- prominente Kurvenfolgen merken (z.B. "rechts-links-rechts" nach Brücke & "Tunnel") - Versuchte mir, Abbiegungen an prominenten Landmarken (z.B. "beim Bahnhof links") zu merken
- Versuchte, mir zu merken, ob Route ein Feldweg oder Hauptstrasse ist oder wenn ich eine Hauptstrasse überquere
- Während Video: Am Startpunkt, als richtig eingelenkt, grobe Richtung (Luftlinie) zum Zielpunkt einschätzen und versuchen, diese Richtung, wenn möglich beizubehalten --> dies führte zu Problemen bei Abbiegungen wie "halblinks" oder "halbrechts" --> konnte immer eine Abbiegung sicher ausschliessen, war mir dann aber trotzdem unsicher, wenn grobe Richtung zum Zielpunkt meiner Meinung nach ähnlich war
- Distanzen vergessen anzuschauen auf Karte --> Massstab wäre wahrscheinlich hilfreich gewesen

Answer 18
Einige Features, die auf der Basemap vorhanden waren, haben mir bei der Orientierung geholfen (z.B. Bahngleise und spezielle Gebäudeformen). Ich denke, dass es mir einfacher gefallen wäre mir die Route zu merken, wenn ich die Karte hätte drehen können, sodass ich mir die Route schon von Anfang an in der "Veloperspektive" hätte merken können. Während der Fahrt war die Entscheidung teilweise etwas erschwert, weil man bei dem Versuchssaufbau (logischerweise) nicht den Kopf drehen und um Ecken schauen konnte. Zusätzlich konnte ich teilweise Abzweigungen auf grössere Distanz noch nicht erkennen. Beim letzten Kreisel habe die Orientierung verloren, da ich die Route am Schluss anders im Kopf hatte, das hat die Weiterfahrt dann stark erschwert. Wenn man einmal nicht mehr weiss, wo man sich befindet, weiss man dann auch nicht mehr, wo man bei den nächsten Abzweigungen abbiegen muss. Mir wurde, während dem Experiment ziemlich schwindelig, das hat allerdings meine Orientierung aus meiner Sicht nicht beeinflusst.

Answer 19
I did most of my navigating by remembering, when to take a turn. i.e. first crossing to the right, two straight, and so on. Or also when there is a "forced turn" i.e. by the end of the road only left or right. This made the decision at the red house (Nr.3) difficult, as I didn't expect three turning options. Then the landmark helped me to recognize where I was on the course. Most of my navigating is done by remembering big streets and intersections and where to go when I reach it. I took the last turn wrong, as i had remembered that I would join back the big road instead of going into the housing. The symbols of the houses are to vague and hard to recognize when faced with it in real life (or through film), as there is only a color to go by and no shape, which I would probably find helpful. The symbols of fountain and bus where helpful, but probably because they occur less often than bigger houses.

3

Answer 20
No influence by dizziness or other factors. In my case the biggest influence was the speed that the video was recorded, and the distance traveled. This made it hard to judge the turns. For example, I was sure that there was a right turn to be made, but couldn't tell for sure if it was earlier or later in the video.

Answer 21
Ich habe nach den ersten Abzweigungen schon ziemlich die Orientierung verloren, und erst bei den Bahngleisen (Unterführung) wieder ein wenig zurückgefunden. Es ist schwer zurück in das sich eingeprägte zu kommen, wenn man sieht, dass die Antwort falsch war und das Fahrrad einen anderen Weg nimmt als man geantwortet hat.

Answer 22
The pictures were sometimes a bit too small to recognize at first glance. E.g., I realized that the building on picture 3 with the distinct facade was also on the map.

Answer 23
Re Q8: I would imagine designing a user-friendly interface with symbols/images would be quite difficult, but if implemented correctly could be helpful. If implemented correctly I'd give a 4. First choice was tricky, because of the Hauptstrasse. At the end it sometimes was more of a guessing game between two likely choices. No dizziness. I would rate myself a 9.9/10.

Answer 24
I have lost track shortly after Landmark 3 and found back to my mental map a bit afterwards.

Answer 25
Die Darstellung der Strassen, sprich gestrichelte Linie für Fuss-Radwege, haben mir zusätzlich bei der Orientierung geholfen. Und die Gebäudeumrisse haben zeitweise auch geholfen, z.B. das Kino oder was das war.

Answer 26
Wenn man die Symbole beim Weg suchen anschauen könnte wäre es vermutlich einfacher. Die Häuser habe ich so fast nicht erkannt. Zum Beispiel das weisse Haus hat mich eher verwirrt da ich dachte es sei neben dem weg und nicht auf dem Weg. Meine Intuition war meist besser als was ich glaubte auswendig zu wissen.

Answer 27
Stopp vor Kreuzung minimal irritierend (beim Kaufhaus), Navigation ein wenig beeinflusst durch Video (Schwenken, holpriges Kopfsteinpflaster, etc.), Überzeugung der eingeprägten Route nach Fehlern etwas weniger gross

Answer 28
Due to the lack of symbols/pictures and houses in general on the map, I focused on the shape of the streets. This worked relatively well, unless for the first of the two "triangular" crossing, which was not yet visible very well in the frame when the video was stopped.

4

Answer 29
Ich habe versucht mir die Anzahl Abbiegungen zu merken und so abgezählt.

Answer 30
Beim Brunnen war ich etwas verwirrt. Da kurz vor dem Brunnen (rechts) auf der linken Seite bereits ein Brunnen war und ich dachte, der wäre auf der Karte eingezeichnet gewesen (wenn auch auf der falschen Seite). Die Häuser habe ich mir gar nicht gemerkt. Da ich mir im Vorhinein nicht vorstellen konnte, wie ich diese Gebäude erkennen wird. Geholfen hat mir der Busbahnhof und die Gleise. Ich wusste, dass die Gleise irgendwann gekreuzt werden müssen. Die Bezeichnungen (sicher, neutral, unsicher) waren teilweise abhängig davon, ob ich den Task vorher richtig gelöst habe oder nicht.

Answer 31
I had trouble remembering the landmarks in two minutes because the houses all look so similar. And it was hard to see any details because the picture was so small. Therefore, I was not able to recognize landmark 4 as a roof.

Answer 32
In der Mitte war es extrem schwer, da ich nicht mehr genau wusste, wo ich mich befinde. Die Bahngleise halfen auch sehr bei der Orientierung. Ich versuchte mir den Weg als grosses Ganzes zu merken, daher ich hatte zwar vor dem inneren Auge eine Vorstellung, wo ich durchfahren musste und in welche grobe Richtung, aber dann bei Fahren sind weniger starke Richtungsänderungen schwierig einzuschätzen.

Answer 33
2 min waren sehr kurz, um sich das Ganze einigermassen einzuprägen, nach der Altstadt war die Orientierung mit am schwierigsten, mega coole Studie!

Answer 34
Erste Abzweigung war auf der Karte gestrichelt dargestellt, musste also ein autofreier Weg sein... Der Park auf halber Strecke habe ich mir gemerkt. Ebenso helfen Kreisel und auffällige Strassenverläufe, sich den Weg einzuprägen. Landmarke 1 und 3 waren die einzig richtig sinnvollen (nach 1 rechts abbiegen, vor 3 rechts abbiegen). Die anderen Bildchen habe ich während des Fahrens kaum mehr bemerkt.

Answer 35
An einem gewissen Punkt war ich überzeugt woanders zu sein, was die zukünftigen Abbiegemanöver bis zum nächsten mental Landmark (bei mir war der nächste Landmark die gerade parallel zu den Gleisen) schwierig machte. Kopfbewegung der Kamera war kein Problem. mein Kopf hatte keine Freude daran, dass die Auflösung das Lesen von Schriften nicht zuliess.

Answer 36
I tried to go the path in my mind while I was trying to remember at the computer. At some point it was useful for the decision making, especially by the landmarks.

5

Answer 37

The route was easier to find in the beginning (open space) and the end (main street along the train station and afterwards the crossing of the train tracks) than in the middle. The old town of Aarau has many different little streets, and many houses look the same, which makes it harder to navigate there. When entering the old town, I didn't memorize to go "through" the white house, which confused my decisions in the following 2 steps.

6

## Declaration of Originality

Personal declaration: "Hereby I declare that this thesis is written independently by the author. Exceptions are corrections of form and content by the supervisors. All literature and information used for the writing of this thesis are referenced and marked."

F. Sturzenegger

Florian Sturzenegger

29.06.2022

Date