Bachelor Thesis

The Effects of Different Verbal Route Instructions on Spatial Orientation

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Abstract

Providing cognitively effective wayfinding instructions is an ongoing research objective. In addition to providing instructions that are efficient to reach a target location, research has also addressed developing instructions in a verbal format that could potentially facilitate spatial orientation and cognitive mapping. In this study, a type of verbal instructions is used that consists of not only essential information for a person to change the direction at decision points, but also additional orientation information along a route that is considered crucial for maintaining spatial orientation and getting an internal representation of the spatial layout. This type of verbal route descriptions is compared with machine-generated as well as skeletal descriptions for the same route. Thirty participants were randomly assigned to familiarize with one of three different types of wayfinding instructions, which described a specific route participants were unfamiliar with. Thus, they were intended to mentally walk along this route. The different types of instructions include: 1) machine-generated instructions, 2) orientation-based instructions, and 3) skeletal instructions. Results indicate that participants using the orientation instructions made least errors in their performance of spatial orientation. Results concerning their drawn sketch maps, however, revealed least accurate results in both landmark placement and route segment analysis among the three types of instructions. Regarding their good performance in orientation estimation, sketch map accuracy is suggested to be secondary concerning performance in spatial orientation and cognitive mapping. Additionally, using the orientation-based instructions type is not found beneficial regarding distance estimation accuracy. The machine-generated instructions with included distance information, however, are not found to lead to a good estimation of distance along the route. This study supports the validity of designing wayfinding instructions in the suggested way. It further implies the necessity to conduct a more comprehensive study on the effects of different types of instructions on various aspects of wayfinding behavior.

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1 Introduction

When giving route directions, in most cases the major purpose is to provide instructions that are efficient to guide a person from one location to another. Such instructions usually include landmarks at decision-making points for reorientation (Michon & Denis, 2001). In this context landmarks serve as crucial elements in wayfinding instructions to support effective and effortless wayfinding as they act as indicators to identify locations in large-scale environments (Siegel & White, 1975; Raubal & Winter, 2002). In addition to the importance of landmarks at decision points, research has recently addressed the importance of landmarks (Lovelace et al., 1999) along routes for the purpose of maintaining orientation (Schwering et al, 2013). Studies have indicated that constructing wayfinding instructions with local landmarks at decision points lead to more efficiency in wayfinding performance (Tom & Denis, 2004). As part of this study, it is further assumed that efficient facilitation for wayfinding addresses not only efficiently guiding a person from an origin to the target of a route, but also spatial orientation during wayfinding. This study contributes to the understanding of landmarks used not only at decision points but also along routes in verbal descriptions. Furthermore, the inclusion of global landmarks is suggested for providing an overall awareness of the respective spatial layout of an environment. Hence, this study aims to investigate the importance of orientation information in verbal route instructions to achieve more efficiency. More specifically, the effects of three different types of verbal wayfinding instructions have been compared. These include: machine-generated instructions constructed by Google Maps, skeletal instructions (Denis, 1997; Denis et al., 1999; Michon & Denis, 2001), and instructions including orientation information. Consequently, the purpose of this study is to investigate the effects of each type of instructions on spatial orientation and cognitive mapping.

The present document is organized as follows. At first, the second chapter introduces research on topics related to this study. Chapter 3 provides details of the experimental setup, whereas the fourth chapter presents the results of the study. After that chapter 5 discusses these results, followed by an outlook on future research directions concerning this topic (chapter 6), and a conclusion (chapter 7).

2 Related work

2.1 Human Wayfinding behavior and Cognitive mapping

When clarifying the importance of this study for investigating the effects of different types of route instructions on spatial orientation, it is crucial to first consider the meaning of wayfinding for human life. This study focuses on the importance of wayfinding for humans, although, as Tolman (1948) concluded in early years of cognitive mapping research, other species like rats also develop cognitive maps of their environment. This chapter introduces the terms *wayfinding* and *cognitive mapping,* which are essential parts of this study.

Wayfinding describes the process of determining and following a route between an origin and a destination (Golledge, 1999). It is necessary to be able to identify the origin and target location for a successful travel. Golledge (1999) further suggests the necessity of determining turn angles, identifying route segment lengths as well as recognizing on-route and distant landmarks. If this is actually the case, when a person is being guided by verbal route instructions, will be discussed later. Why is it so important for humans to develop certain strategies to find a way within an environment? As traveling is essential to human existence, the knowledge of how to get from one place to another is crucial (Kato & Takeucki, 2003). Studies (Prestopnik & Roskos-Ewoldsen, 2000; Kato & Takeucki, 2003) further suggested that people use different strategies when navigating through an environment. Two major types of strategies have been distinguished: The route strategy and the survey strategy. In some literature, the latter is called orientation strategy (Lawton, 1994). Route strategies are characterized by using turn-by-turn directions. In most cases, a sequence of instructions is used, which enable to navigate from an origin place to a target. The focus of this type of strategy is on providing a direct route from one place to another. Hence, a disadvantage of this strategy is that it includes no information regarding the spatial layout of the environment, in which the route is situated. Though, in many cases, distances, street names or landmarks are included, which are located at decision points (Tom & Denis, 2004). A decision point is a location along the route, where the wayfinder needs to reorient and make a choice, where to turn next. This presumes the existence of an intersection with various possibilities of route choices (Denis et al., 1999). However, concerning the route strategy, the provided information is still limited, forcing the wayfinder to rely on the route, in order to successfully reach the target location (Prestopnik & Roskos-Ewoldsen, 2000). In contrast to this, orientation strategies integrate additional information about relations between locations and therefore imply a cognitive map of the environment. Whereas route strategies focus on local entities, which directly concern the route, orientation strategies have a more global orientation. They mostly rely on concepts like cardinal directions, which do not change, when the orientation is changed.

Comparing both strategies, there is a lower chance to get lost for using the orientation strategy. Due to the flexibility of orientation strategies, they facilitate to find shortcuts that deviate from the original route (Lawton, 1994; O'Keefe & Nadal, 1978), or to find the way back to the route after getting lost. Furthermore, it is also possible that one person relies on different strategies, depending on the context. Though, it is more difficult to flexibly choose a strategy that fits the situation best, for individuals with a low sense of direction (Kato & Takeucki, 2003)

Performance in wayfinding is also related to the familiarity with the environment. Wayfinding can take place in both familiar and unfamiliar environments. Familiarity with an environment implies that a person's knowledge concerning the spatial layout of an environment (including knowledge of objects or locations) is much more detailed. In this context, numerous studies (Bryant, 1982; O'Neill, 1992) have suggested an improvement for the performance in wayfinding tasks concerning accurateness, for those who were familiar with the environment.

The concept of a cognitive map has been developed by Tolman (1948) and is used to indicate the internal representation of spatial information, more specifically the perceived environmental features or objects, as well as the spatial relations among them (Golledge, 1999). Whereas the term *cognitive map* has been defined in different ways, it is commonly agreed that cognitive maps consist of points, lines, areas, and surfaces, which are learned, experienced, and recorded in quantitative and qualitative forms (Golledge, 1999). After years of research on cognitive maps, several terms have been established, which can be considered as synonyms. Shemyakin (1962) developed the term *survey knowledge*, which will be discussed in a later chapter. Other designations are configurational (Siegel & White, 1975) and vector knowledge (Byrne & Salter, 1983).

2.2 The role of landmarks

Regarding the role of landmarks for spatial orientation and cognitive mapping, researchers like Golledge (1999) suggest that landmarks usually act as anchor points for organizing other spatial information into a spatial layout. Hence, landmarks act as primary organizing features in cognitive maps.

One important role of landmarks is the identification of particular locations (Downs & Stea, 1973) as they are considered as discrete objects within a spatial context that supports the easy identification of geographical locations (Siegel & White, 1975). A further important role of landmarks refers to their support for reorientation in wayfinding (Michon & Denis, 2001). Studies have suggested using landmarks as a primary or complementary source in wayfinding instructions (Raubal & Winter, 2002) because they are effective for better performance in wayfinding, particularly regarding guidance, fewer wayfinding errors, and shorter wayfinding time (Allen, 2000). For example, researchers like Tom and Denis (Lovelace et al., 1999) compared the use of landmarks in wayfinding instructions with the use of street names. They concluded that using landmarks in wayfinding instructions leads to shorter wayfinding time. Additionally, supporting the importance of landmarks in route instructions, Ross and collaborators (2004) found in their study that using landmarks in route instructions leads to less wayfinding errors.

Spatial orientation is one of the spatial skills that enable wayfinders to be aware of their current locations in relation to destination or other locations in an environment (Golledge & Stimson, 1997). It is most commonly supported by using landmarks. Wayfinders estimate their locations and relationships between current and other locations in the environment to stay spatially oriented through the use of reference systems (Montello, 2005). The reference systems could either be egocentric or geocentric (Hart & Moore, 1973). The use of egocentric reference systems involves using wayfinders' velocity and acceleration information about their own movement (Loomis et al., 1999). In contrast, the use of geocentric reference systems involves the information from the environment. Wayfinders can relate to the features of an environment (i.e. landmarks) and determine the relative locations of themselves or a feature to other features in the environment.

2.3 Local vs. global landmarks

Most of the previous studies concerning the importance of landmarks in verbal route descriptions addressed the use of local landmarks, which are point-like entities on a route (Raubal & Winter, 2002). Only a small number of studies have already considered global landmarks that are off the described route (Schwering et al., 2013). However, global landmarks can support wayfinders to gain a perception of global orientation regarding a specific environment. Therefore, in this study, due to their importance in human wayfinding, both local and global landmarks are considered. To get a better understanding, we first need to distinguish the specific characteristics of both local and global landmarks.

Local landmarks are only visible from a small distance. The most common examples of this type of landmark are distinctive buildings or objects, which are directly linked to the route. This collection of landmarks forms a sequence, with each local landmark representing an intermediate goal. In most cases, local landmarks are located either at decision points or along route segments. According to O'Keefe & Nadal (1978) local landmarks can be used either for guidance or as pointers. For guidance purposes, local landmarks are considered as reference points, guiding the wayfinder to an intermediate goal; introducing local landmarks as pointers implies directing the way onwards from an intermediate goal.

In contrast to that, global landmarks do not only comprise of landmarks which are directly associated with the route, but rather those which are visible from a large area. Steck & Mallot (2000) suggest that global landmarks define a global reference frame, which does not change after moving a short distance. Such global landmarks comprise of city skylines, mountains or tall buildings like TV towers in the distance. The authors further clarify that landmark functions are not unambiguous. This indicates that a landmark, which has been designated as global, may serve as a local landmark in another phase of the wayfinding task, depending on how the wayfinder uses this landmark. Global landmarks are further described to resemble a compass, indicating a special case of guidance (O'Keefe & Nadal, 1978). Other researchers regard global landmarks as off routes, not only point-like, but comprising of a region (Schwering et al., 2013). For such regional landmarks, in some cases, boundaries are indistinct and depend on individual definitions. The city center could serve as an example for a regional global landmark with indistinct boundaries.

In this study, global landmarks are considered as either point-like or regional entities, which not necessarily need to be located off route. As regional global landmarks like the city center are included, their visibility from a large area is of secondary importance.

2.4 Location of landmarks

The location of landmarks described in route instructions has intrigued different suggestions in the literature. For example, it is suggested (Michon & Denis, 2001) that wayfinders would often use landmarks for reorientation that occurs at decision points where a change of direction is necessary. Therefore, no landmark at decision points would become more difficult for wayfinders to determine the locations where they should change heading directions. Moreover, Lovelace and collaborators suggest that landmarks are not only important at locations where reorientation is needed but also essential at locations (potential decision points) where change of direction can be possible (Schwering et al, 2013). At these potential decision points, wayfinders need to maintain their orientation by continuing the same heading direction. The authors emphasize that having brief wayfinding instructions does not automatically translate into good verbal instructions. Consequently, for achieving brief and good verbal instructions, Raubal and Winter (2002) suggested the use of local landmarks for wayfinding instructions by providing measures to identify the salience of a specific feature in an environment. These measures derive from aspects such as visual salience (e.g., facade, shape, color, and visibility), structural salience (e.g., nodes, boundaries, and regions) and semantic salience (e.g., cultural and historic importance of object). Furthermore, Richter and Klippel (2005) address that the route direction should also be context specific as the structure of the environment should be a factor that influences the way how wayfinding instructions should be given. Also aiming to achieve cognitively efficient wayfinding instructions, we introduce a different perspective by looking at the roles of landmarks that are not only at potential decision points.

Most of the existing studies introduced above focus on the roles and use of local landmarks that are on a described route. Limited studies have addressed the roles of landmarks that are distant from a described route as those landmarks in distance serve the important roles of providing general orientation or confirming heading direction (Couclelis, 1996). In this paper, we address global landmarks that facilitate wayfinders to gain the awareness of global orientation. Steck and Mallot (2000) suggested that one or a couple spatial features could be introduced as global landmarks in wayfinding instructions to provide an initial global orientation. Those global landmarks later could be reintroduced as local landmarks if they are actually on a designed route. This hierarchy is also supported by a study of Winter and collaborators (2008). Based on this partition of landmarks, hierarchical communication of space could be achieved that wayfinders would firstly be directed to a prominent global feature, and then specific instructions to the destination are provided. In short, the important role of global landmarks has already been remarked by some studies. We also intend to achieve a better understanding of global landmarks. Therefore we address the use and the role of global landmarks in verbal wayfinding instruction.

In summary, studies have focused on local landmarks and global landmarks in wayfinding. But research on the role of both local and global landmarks for orientation is rather limited. More so, the study of local landmarks was mainly addressing those located at actual or potential decision points. In this paper, we address the use of both local and global landmarks in verbal route instructions. Particularly the location of local landmarks is not only at potential decision points but also along a route. The global landmark is also used adapting the hierarchy suggested by Steck and Mallot (2000). This type of instructions is used to compare with machine-generated and skeletal instructions (Michon & Denis, 2001) to reveal the different effects that each type has on spatial orientation and cognitive mapping.

2.5 Landmark, route and survey knowledge

There are different ways of learning an environment. The two most common ways of learning the layout of an environment are characterized by direct experience through travel, and indirectly by viewing the layout from an overlooking point, by looking on geographical maps (Thorndyke & Hayes-Roth, 1982; Tversky, 1981; Richardson et al., 1999) and photographs, or by spatial discourse (Denis & Zimmere, 1992; De Vega, 1994). In addition, further methods to acquire an internal representation of an environment include the familiarization with videos, sketches or as presented in this study, verbal route descriptions. To which extent the use of verbal descriptions contributes to cognitive mapping, remains to be investigated in the course of this study.

In literature (O'Keefe & Nadal, 1978; Russel & Ward, 1982), three different stages of learning an environment have been distinguished: Landmark, route and survey knowledge. In some cases, landmark knowledge has not been considered as an own stage.

When people get familiar with an environment, they first recognize landmarks, then paths between landmarks, followed by a development of survey knowledge of the key locations (Hunt & Waller, 1999). As a first step of getting an internal representation of spatial information, landmark knowledge is proposed to develop, when an individual acquires knowledge about landmarks as unique objects at fixed locations. Although it is possible to recognize a multitude of landmarks, at this stage, there is no or very limited knowledge about the orientation of landmarks to each other, as well as a connection between them (Werner et al., 1997).

For acquiring route knowledge, the major concern is to learn the structure of the route as a sequence of route segments (Golledge, 1999) or objects and events (Werner et al., 1997). Very few spatial entities along the route are needed to be remembered, though it is essential to learn landmarks at decision points to make sure not to miss a turn.

Survey knowledge however, includes knowledge about not only the route itself and its direct surroundings, but also the environment, in which the route is located. Shortcutting serves as an indication for the existence of survey knowledge, as in this case, the person not only gained knowledge of the route, but also about the spatial layout of an area. For this, connections between the route and other paths within the environment need to be stored in the cognitive map of a person (Golledge, 1999). Particularly, the development of survey knowledge regarding a specific environment is not always achieved for every person, even after years of experience and familiarity. This is caused by large individual differences concerning orientation abilities (Hunt & Waller, 1999). In some cases it is difficult to determine if a person has acquired landmark knowledge, route knowledge or survey knowledge of an environment. This is, because the different stages of learning an environment underlie indistinct boundaries (Werner et al., 1997).

2.6 Verbal Route Instructions

Whereas the majority of studies on cognitive maps have addressed situations in which participants gain direct perceptual experience or indirectly by symbolic material

(Denis & Zimmere, 1992), this study concentrates on the role of language regarding the acquisition of spatial knowledge and orientation information. Though, this is not the only factor which can possibly influence cognitive mapping. Studies have shown that humans particularly acquire spatial knowledge through direct perceptual and navigational experience (Golledge et al., 1996; Cornell et al., 1994). Other factors include actions like learning symbolic information from a map (Thorndyke & Hayes-Roth, 1982), navigating through a computer-generated virtual environment or listening to descriptions. Research on language as a means of acquiring and externalizing spatial knowledge has only developed in recent years (Daniel & Denis, 1998). Specific cases of a description including language in a spatial context are route directions or route instructions. The influences of different route instructions on spatial orientation, given in a verbal format, are investigated in this study.

In some literature the verbal output of giving route directions (Denis et al., 1999) is differentiated in two components. According to Denis and collaborators (1999) the verbal output is a composite of a description and an instruction, whereas descriptions describe the nature and position of landmarks along the route and instructions however specify, which actions should be executed at critical points along a route. As all the three types of route directions used in this study include actions to be executed at decision points as a major component to guide a person from a starting point to the target, these route directions are henceforth termed as verbal route instructions.

When giving route directions, in most cases the major purpose is to most efficiently guide a person from one place to another in an unfamiliar environment (Denis et al.; 1999). In this context, research has also focused on investigating, which characteristics route instructions should contain for being denoted as ‘good route directions’ (Lovelace et al., 1999). Accordingly quality measurement of route directions can be distinguished in three different ways. The first approach proposes to assess the quality regarding the absolute number of elements included in the verbal output. These elements could include landmarks, descriptive information or turns at intersections, which are assumed to support route following. If the quality of these elements has also an effect on cognitive mapping, remains to be discussed later in this study. Other methods for measuring route direction quality address subjective assessment by using a rating scale and a functional approach. This means, how efficient the directions support the completion of the corresponding wayfinding task. According to their high subjectivity, depending on many different factors, there is no definition that unequivocally describes the characteristics of good route instructions. However, in most cases based on empirical evidence, researchers (Allen, 1997; Mark & Gould, 1992) have suggested some aspects of route directions to be particularly important. These aspects especially comprise the mentioning of landmarks at decision points, using landmarks instead of street names, providing distances between decision points, giving statements that support wayfinders to find the way back to the route in case a decision point has been missed, and providing a limited amount of redundant information.

Consequently, it is assumed that the ways how the verbal descriptions are written affect the resulting mental representations of a person. These representations could be either map-like or route-like (Denis & Zimmere, 1992). Perrig & Kintsch (1985) concluded that different forms of verbal route descriptions also contribute differently to a person's mental representation of an environment. In the following section, the different types of verbal route instructions used in this study are described; also with respect to their possible efficiency in wayfinding tasks, under consideration of the previously named important aspects of route instructions.

2.7 Types of route instructions

2.7.1 Machine-generated instructions

In this study, for the machine-generated instructions type, directions constructed by Google Maps have been used. Machine-generated instructions are primarily marked by their turn-by-turn characteristics, being reduced to instructions like 'Turn left', 'Turn right' or 'Continue' onto a specific street. Another conspicuous characteristic is that all spatial entities included in this type of instructions are street names. For this experiment, an exception has been made regarding the inclusion of the origin and the target of the route in the descriptions. This has been required for the participants to complete the direction and distance estimation tasks, which are described in the third chapter. Apart from that, machine-generated instructions by Google Maps include no landmarks, though distance information for each route segment.

The current version of Google Maps also provides arrows, which each indicate the direction of the following route segment. These arrows visualize a turn action at a specific interaction and can support people in understanding directions. But as signs like these are symbolic representations of spatial activities and the current study only addresses verbal instructions, they have not been considered.

Furthermore, Google Maps provides the option to choose between five different transportation modes; distinguishing between travel by car, public transportation, foot or bike. If the distance between the origin and the target of the route is long enough, another option would be choosing a route by plane. What is most apparent is that especially instructions by car, foot or bike, have in common that they only include street names as spatial features. However, whereas these turn-by-turn instructions might be efficient to guide a person from the origin to the target of a route, in contrast, humans tend to provide verbal route instructions in a different format. Schwering et al. (2013) investigated that instead of relying exclusively on street names, in most cases humans include landmarks as an aid for maintaining spatial orientation while walking along the route. The importance of landmarks for spatial orientation will be further investigated in the following chapters.

2.7.2 Skeletal descriptions

The term ‘skeletal descriptions’ has been established by Denis (1997) and has been investigated in several further studies (Daniel & Denis, 1998; Denis et al., 1999). It describes a type of wayfinding instructions consisting of a minimum set of route instructions with landmarks only located at decision points, while remaining fully informative to support wayfinding. Skeletal wayfinding descriptions are reduced to those pieces of information which are essential but sufficient to guide a person to a goal without any other additional aids (Denis, 1997). These kinds of instructions include landmarks only at decision points, indicating these landmarks as primary anchors for the area (Golledge, 1999). The original procedure of constructing skeletal descriptions (Denis et al., 1999) includes extracting the essential information concerning the route from a set of more detailed, individual descriptions collected by participants beforehand. Individual descriptions revealed a variety of ways to describe a route, whereas, most conspicuously, the placement of landmarks has generally been concentrated at decision points, where a change of direction needs to be made.

In a further step, the instructions provided by the participants were arranged together to construct ‘megadescriptions’ of the corresponding route. Afterwards, redundant information has been deleted to produce more abstract, ‘skeletal’ descriptions; a minimum set of instructions comprising only of essential actions and landmarks at decision points, which are needed for navigation. In a subsequent study, participants (familiar or unfamiliar with the environment) other than those, who gave the individual descriptions, selected information they evaluated to be necessary and sufficient to guide a person travelling along the route. Interestingly the contents of the resulting skeletal description were similar, indicating that both participants, who were familiar or unfamiliar with the environment, can judge the relevance of information in route directions, regardless of their knowledge of the environment described. Regarding the actual navigational performance, skeletal descriptions reached similar error scores as individual descriptions, which have been rated as 'good' clarifying their efficiency as navigational aids. Due to their efficiency in guiding a person along a route, skeletal descriptions support the importance of landmarks as key components of route instructions.

2.7.3 Including orientation information in verbal route instructions

When thinking of route directions, in most situations their primary requirement is to guide the way from one location to another most efficiently, without considering the chance that a person might miss a turning point and gets lost. But what happens when we get lost? We need to find the way back to the last location, which is described in the instruction; or alternatively, if possible even find a shortcut that leads to another point on the route or the target. Admittedly, for this kind of action, knowledge of the route itself is not sufficient. Especially shortcutting requires the existence of a cognitive map of the environment, in order to reliably move around the environment, even off routes. Therefore it is important to provide route instructions, which include information that support spatial orientation and cognitive mapping (Schwering et al, 2013).

Providing orientation in verbal route instructions primarily addresses the inclusion of landmarks. Whereas local landmarks at decision points primarily act as navigational aids to facilitate the location of turning actions, landmarks along the route serve to support maintaining orientation. Despite the efficiency of local landmarks to provide spatial orientation, when walking along the route, this does not imply the formation of a cognitive map of the area. Studies on sketch maps reveal that global landmarks are frequently used in sketches, which provide global orientation (Schwering et al., 2013). In this context, similarly, the introduction of global landmarks in verbal route instructions for facilitating to gain awareness of global orientation during wayfinding is suggested.

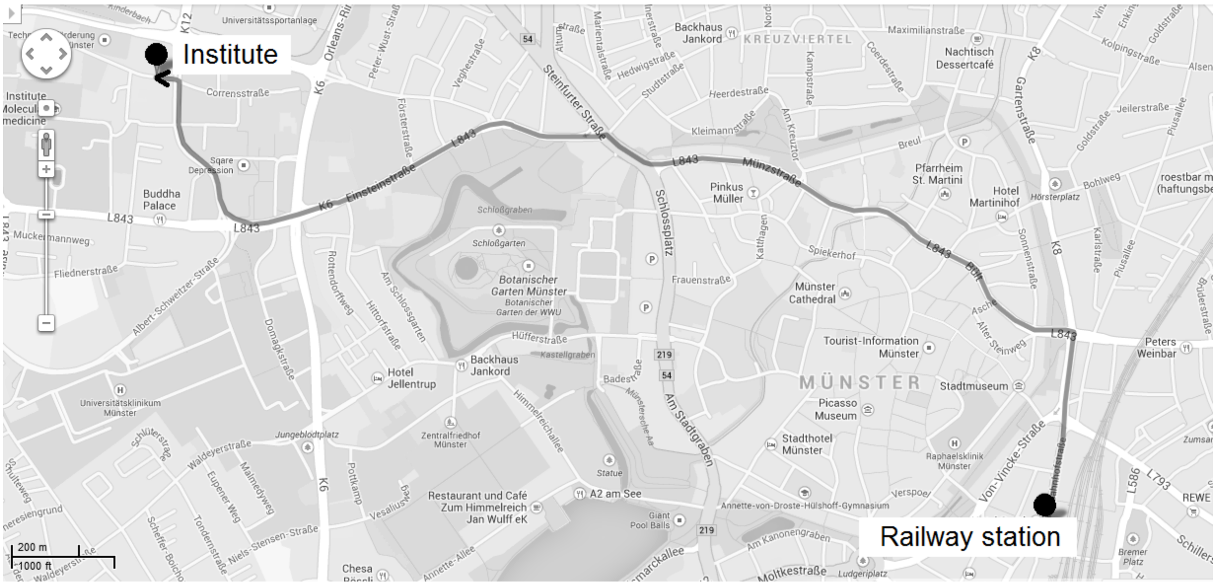
Researchers like Steck and Mallot (2000) suggest that spatial features could be introduced as global landmarks in wayfinding instructions to provide an initial global orientation. Consequently, it is assumed that the way, how the verbal description is written, affects the resulting mental representations of a person. These representations could be either map-like or route-like (Denis & Zimmere, 1992). In this study, a verbal route description is provided, in which the city center serves as a global landmark.

3 Methods

3.1 Materials

To address the questions that are raised in the above sections, an experiment on the effects of different types of verbal wayfinding instructions on spatial orientation has been designed. According to the model of route direction production, proposed by Lovelace et al. (1999) this procedure contained three major steps. As a first step, spatial knowledge of the environment is required. This is necessary to construct directions, which are correct and unambiguously understandable. Secondly, a route has been selected, which is located in the city of Münster, Germany. The start location is the central railway station; the destination is the institute building. The length of the selected route is approximately 3.9 km (3 km air distance). As a third step, based on this route, three different types of verbal route instructions have been constructed. The study area as well as the route including the origin and the end locations are shown in Figure 1 below.

Figure 1: Study area and selected route with origin (railway station) and target (institute).



Source: Google Maps.

The primary research goal is to investigate how a new and unknown route description contributes to spatial orientation without the influence of the familiarity aspect. Thus, the tasks should be completed independent of previously gained experience and knowledge concerning the study area. In order to avoid the influence of the participants' familiarity on their performance in this experiment, we changed the names of spatial entities in all our verbal descriptions to provide route instructions to which all participants are not familiar with. As the majority of the participants were inhabitants of Münster, the study area has been introduced as a not specified German city of similar size and shape as the actual city: A mid-size German city with an old town in its center and a ring-like arrangement of streets. The route itself remained the same, whereas street names and landmarks were changed in the route descriptions, without altering their positions on the original route. For example at the original location, the railway station was replaced by the name of a fictional cinema, whereas the original location of the institute building was accordingly replaced by the name of a fictional library.

Three different types of wayfinding instructions have been constructed. Each type describes the same route between the above named locations. Table 1 provides an example of the differences in the three types of instructions for the route used in this study. Concerning the numbering of the different types, the order is kept up during the whole study. The complete sets of instructions can be found in the appendix.

Table 1: Three different types of instructions for the same route segment.

Type	Instructions
1. Machine-generated	Turn left onto Bismarckstraße and drive 350m; Continue onto Schillerstraße for 650m; Continue onto Kreuzstraße for 140m.
2. Orientation-based	Follow the street, which is heading away from the city center; You cross the intersection on the ring road that runs around the city; Right after you pass the university main building on your right hand side, you reach an intersection.
3. Skeletal	Walk along the street; Right after you passed the university main building, which is on the right side, you reach an intersection.

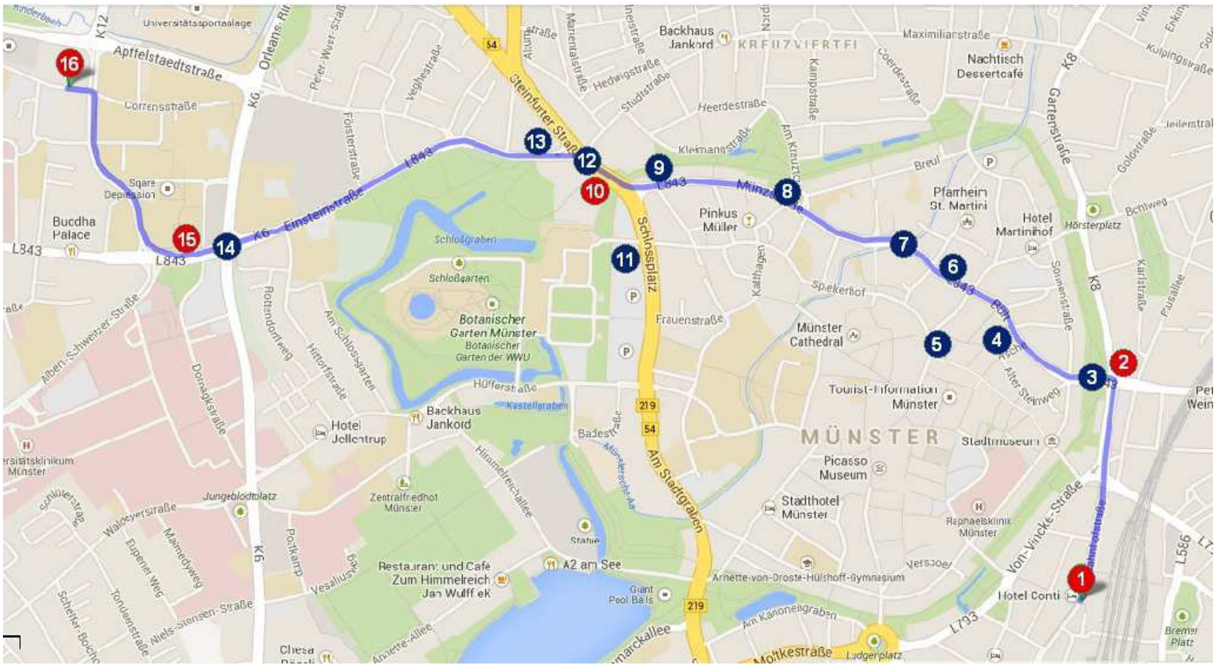
The first type consists of a route description derived by the machine-generated route instructions from Google Maps. This type of route instructions is primarily marked by its turn-by-turn characteristics. According to the purpose of guiding a person from a starting point to a target location, machine-generated route instructions are in most cases composed of street names and distance information, as well as turn instructions without specifying any landmarks along the route. The second type provided a route description with additional orientation information to support spatial orientation and wayfinding. These descriptions contain local landmarks alongside the route, as well as global landmarks off the route.

The third type has been constructed according to the method of skeletal descriptions, designed by Denis (1997) and used in later studies (Denis et al., 1999; Tom & Denis, 2004). This type of instructions consists of a minimum set of wayfinding instructions with landmarks only at decision points, while remaining fully informative to support wayfinding.

A total of 16 landmarks have been determined for the description of the route. The actual number of landmarks varies depending on the type of instructions. Whereas the machine-generated instructions do not include any additional landmarks except the origin and the target of the route, the instructions with included orientation information presented in this study contain 16 landmarks both on and off the route. Landmarks for this type can be local or global. For the skeletal instructions, landmarks were reduced to five, covering only those located at decision points.

Figure 2 shows the entirety of all landmarks, which are named in either the orientation-based instruction or the skeletal instructions, at their correct geographical location. Landmarks, which are only specified in the orientation-based instructions, are illustrated as a blue circle. Red circles, however, indicate landmarks which are named in both orientation-based and skeletal instructions. The numbers within the circles indicate the sequence of landmarks according to the instructions. Furthermore, landmarks both on and off the route are visualized.

Figure 2: Actual geographical location of all landmarks, which occur in the instructions.



Source: Google Maps.

An overview of all landmarks with their designation in the instructions is provided in Table 2. Here the ID refers to the numbers in the map above, in order to simplify the localization of each landmark on the map. Please note that the names of the landmarks in the instructions can differ from those they refer to in the real environment, due to the above mentioned change of names. In addition, each landmark has been assigned a function, indicating if a landmark is either considered as local or global in the context of the route and the environment. Most of the landmarks included in the instructions are local, particularly those, which are included in the skeletal instructions. This is because this type only allows landmarks on the route, which are located at decision points. As indicated earlier, regarding the three types of instructions, global landmarks can only be included in the orientation-based instructions. Examples for global landmarks are the *Stadtwall*, which is crossed twice and denotes a city wall around the old city center, the *Marienkirche*, describing a church with a tower that can be seen from different positions along the route, the regional landmark *Burgplatz*, indicating a large square located off the route, as well as the *Ringroad* with similar properties like the Stadtwall. 'Stadtwall' and 'Ringroad' are suggested to be declared as global landmarks, because they provide a first, coarse impression of the spatial layout of an area or the city.

Table 2: Landmarks in the sequential order as they occurred in the instructions.

Landmark	ID	Function
Cinema	1	Local
Clock tower	2	Local
Stadtwall	3	Global
Shopping center	4	Local
Marienkirche	5	Global
Theatre	6	Local
River	7	Local
Pulverturm	8	Local
Stadttor	9	Local
Flag-building	10	Local
Burgplatz	11	Global
Ancient buildings	12	Local
Gas station	13	Local
Ringroad	14	Global
University	15	Local
Library	16	Local

As a particularly important global landmark for maintaining orientation, the city center is suggested to serve as a reference area, which occurs repeatedly in the orientation-based instructions. Particularly, it is the only type of instructions, where the location of the city center is mentioned specifically. As this is considered to be a special case, where the extent depends on individual definitions, this global landmark is not illustrated in the figure above.

3.2 Participants

A total of 30 participants (Age: M = 29.75, SD = 10.65; 17 men and 13 women) were recruited. To ensure equal conditions, each of the three types of route instructions has been assigned to the same number of participants, including each 10 participants. Furthermore, gender has been balanced, with approximately the same number of females and males in each group. Participants were not exclusively students and ranged in age from 19 to 66 years.

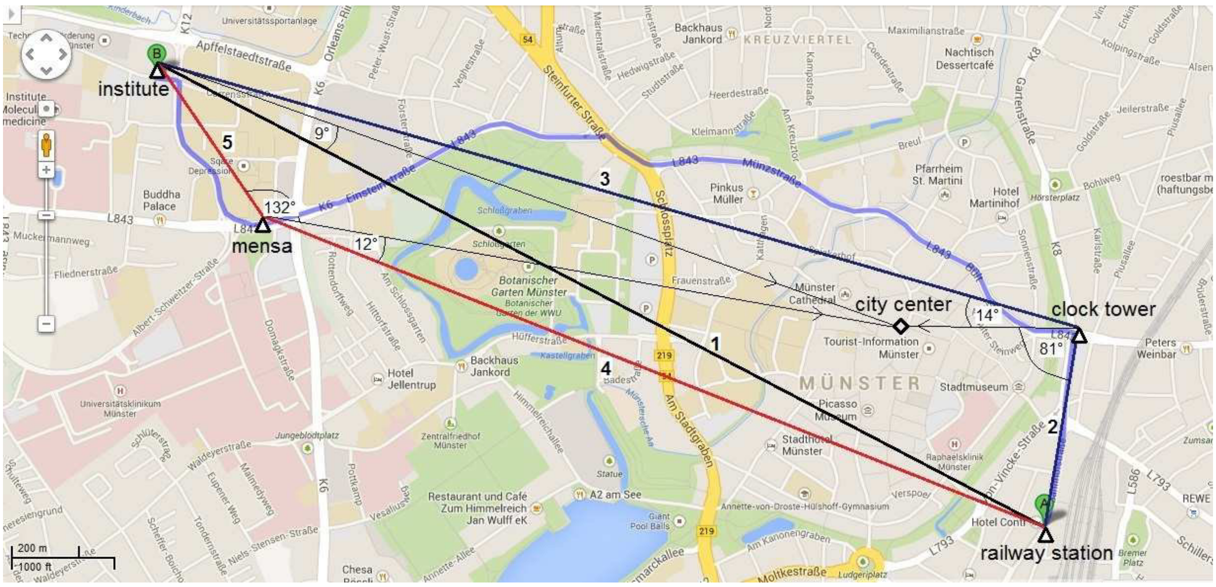
3.3 Procedure

After providing the participants with a short overview of the conditions during the experiment, they randomly received one type of wayfinding instructions to familiarize with, so that for each type there would be approximately the same number of male and female participants. To address the fact that generally, learning from verbal descriptions requires longer processing than learning from maps (Perrig & Kintsch, 1985), participants were asked to read through the instructions several times before starting with the first task. Throughout the whole procedure there was no time limit. Additionally, participants also had the chance to look upon the instructions during the whole experiment, but were not allowed to use external aids except the material they received for completing the tasks. Participants were then asked to complete different tasks according to the route instructions they received. The first task of the experiment included drawing a sketch map of the described route from the main railway station (origin) to the Geo1-building in Münster (target), the current location of the Institute for Geoinformatics. To complete this task, participants were asked to include as much spatial entities as possible. These could contain streets, objects and areas.

The second exercise has been prepared as a combined task for direction and distance estimation. The first subtask included estimating the direction from the target back to the origin of the route while facing the city center as well as judging the corresponding air distance in meters between both locations. The city center serves as a reference direction in each of the tasks. According to the characteristics of each type of instructions explained above, the orientation instruction type is the only type containing the city center. For the second and the third subtask, participants needed to mentally change to another position at the route and again pointing to the origin and the target of the route. Depending on the type of instruction, this could be an intersection or a specific landmark.

Figure 3 below shows the actual directions for each of the direction estimation tasks in the real environment and the corresponding angles between these directions and the viewing direction (city center). The direction for subtask 1 is marked as a black line, subtask 2 as blue and subtask 3 as red lines. Numbers next to the lines refer to the corresponding connections in Table 3. This table also provides the actual distances for each connection.

Figure 3: Directions and actual angles for the Direction estimation task.



Source: Google Maps.

Table 3: Actual distances for each connection in the distance estimation task.

Connection	Distance in meters
1	3000
2	600
3	2800
4	2500
5	500

To complete the experiment, each participant was asked to do a spatial ability test and fill in two self-rated questionnaires, including the Purdue Spatial Visualization Test for Rotations (Guay, 1976) the Santa Barbara Sense of Direction Scale (Hegarty et al., 2002) and the Spatial Anxiety Scale (Lawton, 1994). Whereas the two previous tasks directly refer to the route instructions, the remaining tasks primarily serve to assess the level of experience in spatial knowledge of the participants.

After completing these tasks, hereinafter, participants were asked to fill in a final questionnaire, which provided the chance to evaluate the tasks concerning their difficulty as well as commenting on the procedure of the experiment. Participants needed to indicate their level of experience in performing wayfinding tasks related to the one presented in this study. Furthermore they were asked to specify, if there were tasks that were particularly difficult or particularly easy for them. Finally, participants needed to estimate how accurate their work has been.

Throughout the whole procedure of the experiment, participants were allowed to ask questions, if they had difficulty in understanding the instructions or the tasks. There has been no time limit for completing the tasks. Even though time may also have an influence on performance in tasks like those presented, this aspect is not intended to be investigated as part of the study.

3.4 Description of measurements

For the direction estimation task, participants needed to estimate directions of different target locations from changing points of view. Prior to the evaluation of the participants' estimates, the actual directions from the origin location to the start location have been determined. The direction between both locations is indicated by a specific angle between the straight line connecting the origin and the target and the viewing direction from the estimation origin to the city center (Figure 3). Although being a global landmark covering an area with indistinct boundaries, the location of the city center needed to be determined unambiguously as a reference location for evaluation purposes. As the study area has been introduced as a midsized German city with an old town in its center, the city center has been determined as a point between Domplatz and Prinzipalmarkt, which is located in the very heart of the old town of Münster. This method allows calculating the direction estimation errors between the estimated angle and the actual angle, which are in the following used for comparison with other measures. Figure 3 provides an overview of the actual angles, which have been measured.

The results for the distance estimation task have been evaluated similarly. To obtain the distance estimation error, the differences between the previously determined air distances (Table 3) within the real environment and the distances estimated by the participants have been calculated. These values have been used for further evaluation and comparison with other measurements.

For the spatial ability test, six tasks of the original Purdue Spatial Visualization Test for Rotations (Guay, 1976) have been used. Depending on the count of correct answers, each participant reached an individual score, with a maximum score of 6. Furthermore, the scores of the spatial anxiety scale have been reversed so that a higher score indicated a higher level of anxiety. A similar approach has been applied for the Santa Barbara Sense of Direction Scale. Here, the positively stated items were reversed so that a higher score indicates a better sense of direction (Hegarty et al., 2006).

3.5 Hypothesized results

Prior to the conduction of this study, the following hypotheses have been assumed. The first hypothesis is that all three types of verbal route instructions will contribute differently to spatial orientation. As the second type of instructions includes additional orientation information, for this type the direction estimation errors will presumably be considerably fewer than for the skeletal and the machine-generated type of instruction. This is supposed to be reflected in the sketch maps, marked by a higher accuracy for the orientation of route segments and a more accurate arrangement of landmarks for type 2 sketches. In contrast, the results for estimating distances are supposed to be most accurate for the machine-generated instruction type, as it contains distance information for each segment of the route. Due to the lack of information, which is needed to maintain orientation in a certain environment, the results for the instruction type based on the skeletal descriptions are not presumed to be accurate for both the direction estimation and the distance estimation tasks. That is to say that in contrast to the orientation-based instructions, both machine-generated and skeletal instructions is hypothesized to be efficient in guiding a person along a route, but not in their contribution to spatial orientation.

The second hypothesis relates to the influence of self-estimations on the results of the wayfinding tasks. It is presumed that if an individual has a low level of Spatial Anxiety and reached a high score for the Sense of Direction Scale, the performance in the estimation tasks and drawing the sketch map is supposed to be accurate, too. This should also apply to individuals, who have reported to be experienced in doing wayfinding tasks. Also, spatial anxiety and sense of direction are assumed to be negatively correlated, indicated by a generally lower level of spatial anxiety for persons with a good sense of direction.

The third hypothesis assumes gender differences in spatial orientation abilities. Based on previous findings from Lawton (1994) the level of spatial anxiety and the performance in mental rotation tasks is presumed to be higher for women than for men. Furthermore, research on gender differences in wayfinding abilities propose that men are more likely to use an orientation strategy, while women mostly rely on route strategies. This implies that males are more likely to be able to maintain a sense of their own position, whereas females stick to instructions on how to get from one point to another (Lawton, 1994). Therefore, in this current study, it remains to be investigated, if these findings can also be transferred to the estimation of orientation tasks. Presuming yes, females should be less accurate in estimating directions according to the route instructions they receive. Though, the difference in performance between females and males should not be very distinctive especially regarding the machine-generated instructions, as these are most related to the route strategy. Similarly, distance estimation is assumed to be gender dependent, favoring males.

The fourth hypothesis presumes relations between the direction and distance estimation accuracy and the corresponding sketch map alignment. Here, the errors regarding the orientation of route segments in the sketch maps are assumed to correlate with the direction estimation errors. Similarly, the distance errors which indicate the deviation are supposed to be similar for both sketch map and estimation tasks.

Finally, based on the previously explained assumptions, the efficiency of wayfinding and spatial orientation is hypothesized to be achievable through orientation-based route instructions.

4 Results

Analysis of the collected data has been carried out as follows: At first the participants' performances among the three different types of verbal wayfinding instructions will be compared regarding the estimation of orientation and distance estimation. After that, sketch maps are going to be evaluated with respect to the orientation of route segments and the orientation of landmarks. At last, further influences on spatial orientation, as well as the participants' performance on self-rated measures and spatial skills will be examined.

4.1 Direction estimation

In this section, the results for the direction estimation (or sometimes referred to as orientation estimation) tasks will be presented. Analysis of the results refers to each subtask separately, as well as to the average of all direction estimation tasks among all participants.

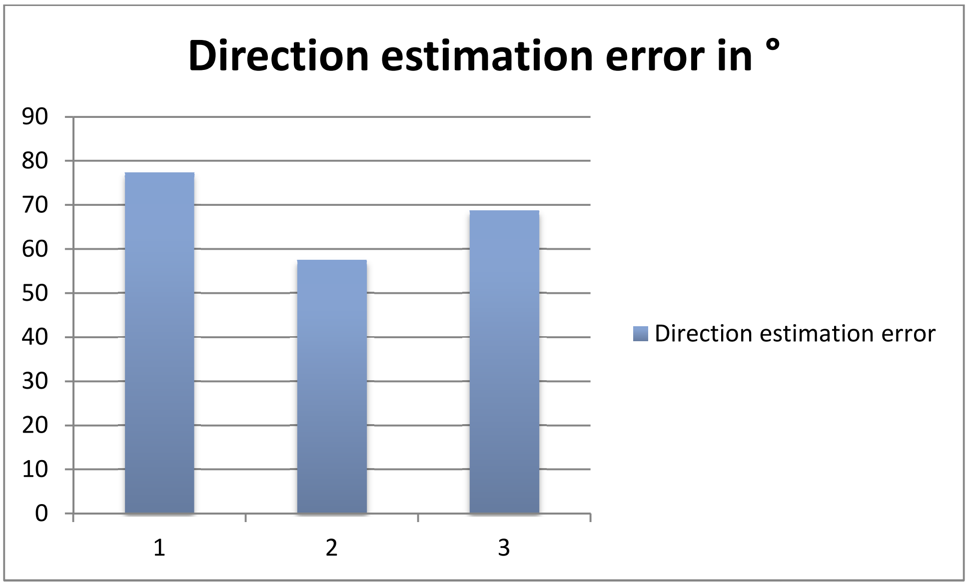
Table 4 compares the average direction estimation errors for each of the instruction groups, by considering the values for each of the subtasks separately. As previously hypothesized, the direction error average combined for all tasks is lowest for the orientation based instructions group, whereas for the machine-generated instructions group, direction estimation has been found as most incorrect among all groups. Concerning the skeletal route instructions, the direction estimation error average reaches an intermediate value. Figure 4 illustrates these results.

However, unexpectedly, considering only the first subtask of the direction estimation task, which included estimating the direction from the target back to the origin of the route, results reveal no advantage in using the orientation-based instructions. Indeed, the average error for this type hardly differs from the one of the machine-generated instructions. Instead, participants using the skeletal instructions reached the most accurate results among all instruction groups for this subtask.

Table 4: Descriptive statistics for each of the direction estimation tasks separately and combined for all tasks, compared by instruction type.

Direction error	**Combined**		**1st subtask**		**2nd subtask**		**3rd subtask**	
Instruction type	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Machine-generated	77.40	26.43	61.60	51.79	65.58	27.01	104.75	51.77
Orientation-based	57.50	25.25	60.20	38.69	52.50	28.40	59.80	42.92
Skeletal	68.72	34.87	53.80	38.34	57.70	50.49	87.95	42.27

Figure 4: Average direction estimation error among all three types of instructions.



Comparing the direction estimation performance for males and females, no significant gender differences have been observed, $F < 1$. However, results show that the direction error average is slightly lower for females (M = 68.38, SD = 24.42), indicating a fractional better accuracy in judging directions than for males (M = 70.04, SD = 34.94).

Results further show that age has no significant influence on direction estimation accuracy, $F < 1$. For comparison purposes, the age variable has been divided into two groups comprising of the same number of participants. For splitting up the age variable, the median value (27.50) has been taken as a reference. Group 1 includes 14 participants up to an age of 27; group 2 comprises the remaining 14 participants, who are 28 years or older. Two participants refused to indicate their age; therefore they have not been assigned to an age group. The purpose of the selection of this classification is to construct groups, which consist approximately of an equal number of participants in each group. Results show no distinctive differences for direction estimation accuracy regarding age groups, indicated by similar average error values for age group 1 (M = 68.63, SD = 30.25) and age group 2 (M = 70.23, SD = 28.78).

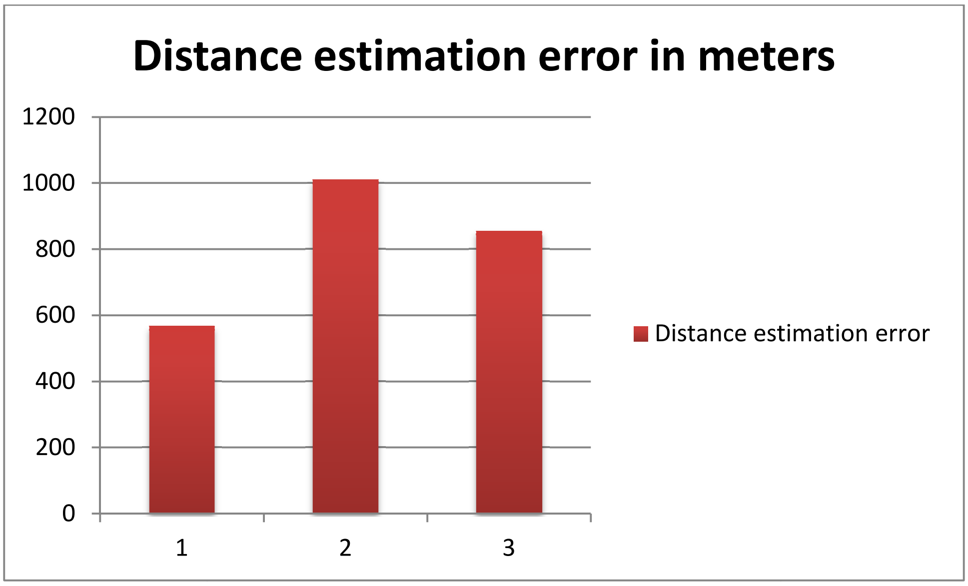
Regarding a possible influence of a participant's experience in completing wayfinding tasks, no significant differences have been found, $F < 1$. Nevertheless it is worth noting that participants, who reported to never have done a related task (M = 65.89, SD = 26.41) performed better than participants, who have done one similar task previously (M = 70.56, SD = 23.64) or have done similar tasks several times before (M = 72.17, SD = 48.48).

It is interesting to note that the direction error average was lowest for those participants, who reached a low score in the spatial ability test with only two correct answers (M = 47.25, SD = 37.12), whereas for participants, who reached the high score of this test, the direction estimation error is distinctively larger (M = 67.26, SD = 33.67).

4.2 Distance estimation

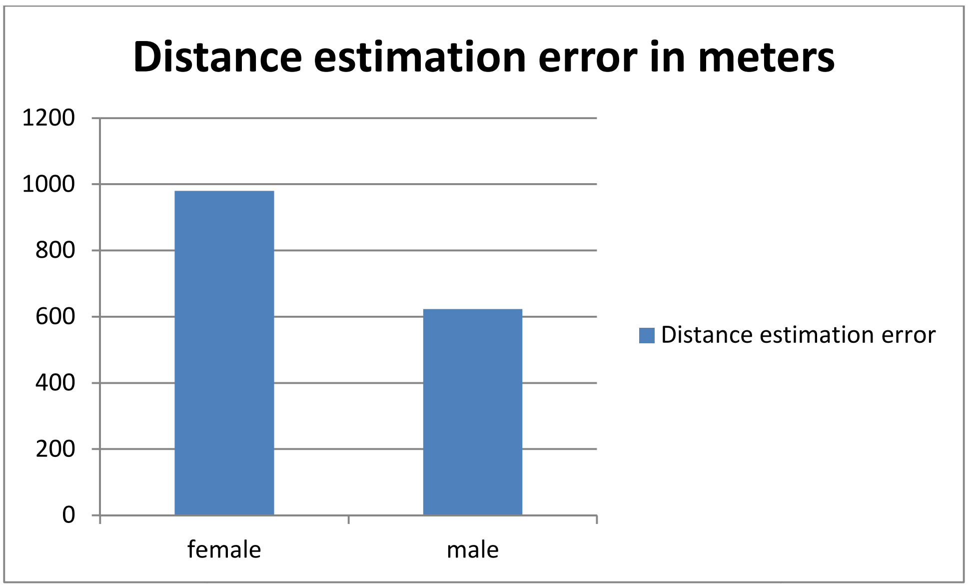
Results for the performance in the distance estimation tasks combining all tasks show no significant differences among the three instruction groups, $F(2, 24) = 2.63$, $p > .05$. Yet, the average distance estimation errors for the three groups provide revealing results (Figure 5). Not surprisingly, the average value for the machine-generated instruction group with included distance information is lowest among all groups (M = 567.50, SD = 371.72), although not as low as expected. Skeletal route instructions (M = 855.56, SD = 436.19) however, despite the very limited information content they provide, are found to lead to more accurate distance estimations than orientation based instructions (M = 1010.83, SD = 455.71). Whereas the influence of the different instruction groups on the average distance estimation error among all tasks has revealed no significant effects, considering only the performance in the first subtask of the second distance estimation tasks, results have been found significant using a one-way ANOVA, $F(2, 24) = 10.00$, $p = .001$. Detailed results concerning average values support the assumption that participants benefited most from the machine-generated instructions types in distance accuracy (*M* = 127.00, *SD* = 154.49). Skeletal (*M* = 327.78, *SD* = 125.28) and orientation-based instructions (*M* = 412.50, *SD* = 138.23), however, did not lead to an accurate estimation of distance.

Figure 5: Average distance estimation error among all three types of instructions.



Results also indicate significant gender differences in estimating distance favoring men by using one-way ANOVA, $F(1, 25) = 5.02$, $p < .05$. The average distance error is distinctively higher for females (*M* = 980.13, *SD* = 402.14) than for males (*M* = 622.86, *SD* = 424.41). Figure 6 illustrates this relationship.

Figure 6: Average distance estimation error regarding gender.



For the distance estimation task, no significant age-related differences have been found, $F < 1$. However, in contrast with results for the direction estimation error average, for the distance estimation tasks, an age-related decrease of inaccuracy in judging distances has been observed. These results indicate that older individuals appear to be more accurate in estimating distances within an environment. While results for age group 1 are marked by a relatively high distance error average (M = 878.21, SD = 523.55), a lower error has been observed for age group 2 (M = 739.39, SD = 339.29).

Concerning the influence of spatial abilities on distance estimation accuracy, no significant results have been observed, $F(6, 20) = 1.36$, $p > .05$. Nevertheless, comparing the means for the different scores of the spatial ability test, unexpectedly, those who performed best, made most errors in estimating distance. This is indicated by a larger distance estimation error mean for participants who reached a score of 5 (M = 871.30, SD = 375.81) or 6 (M = 853.33, SD = 485.45) than for participants who reached a low score of 2 (M = 641.67, SD = 553.90).

4.3 Sketch maps

In a further step, the sketch maps drawn by the participants have been analyzed regarding their contribution to spatial orientation. The evaluation of these hand-drawn maps has been completed in two different ways, which are described separately in the following chapters.

4.3.1 General observations

Before going into more detail, some general observations should indicate a direction and serve as a basis for the analysis of sketch maps. Comparing the sketch maps among the three different groups of instructions, each type has its own distinctive characteristics. To get a better impression of the respective layout of these sketch maps, a total of six sample sketch maps have been selected, which represent the particularities of each instruction group most appropriately. These sketch maps have been split up in two illustrations. Figure 7 and Figure 8 each show three sample sketch maps, one for each type of instruction group. Please note that the bold numbers are used to associate them with the corresponding instruction type.

Figure 7: Sketch maps drawn by the participants – example 1.

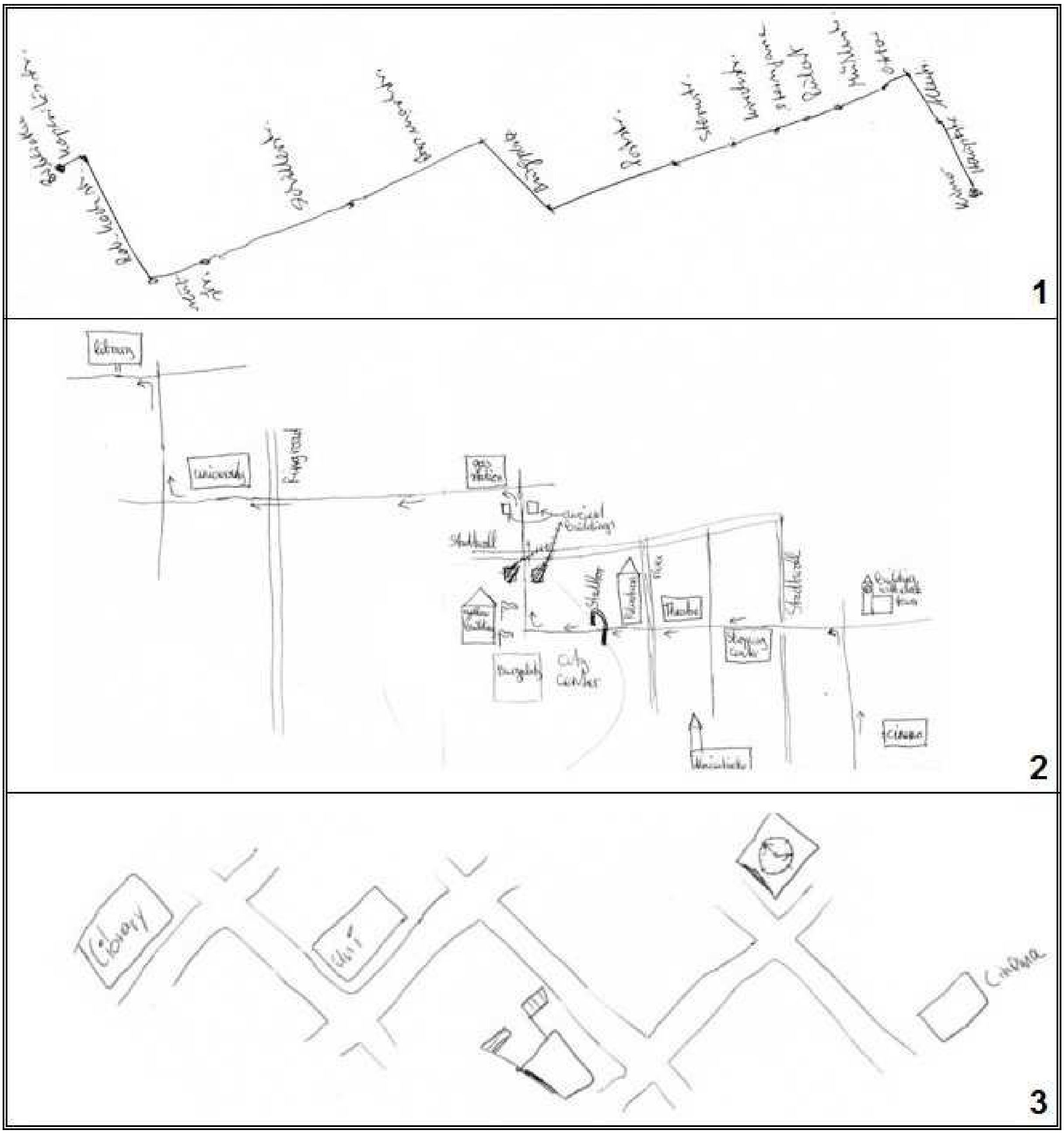
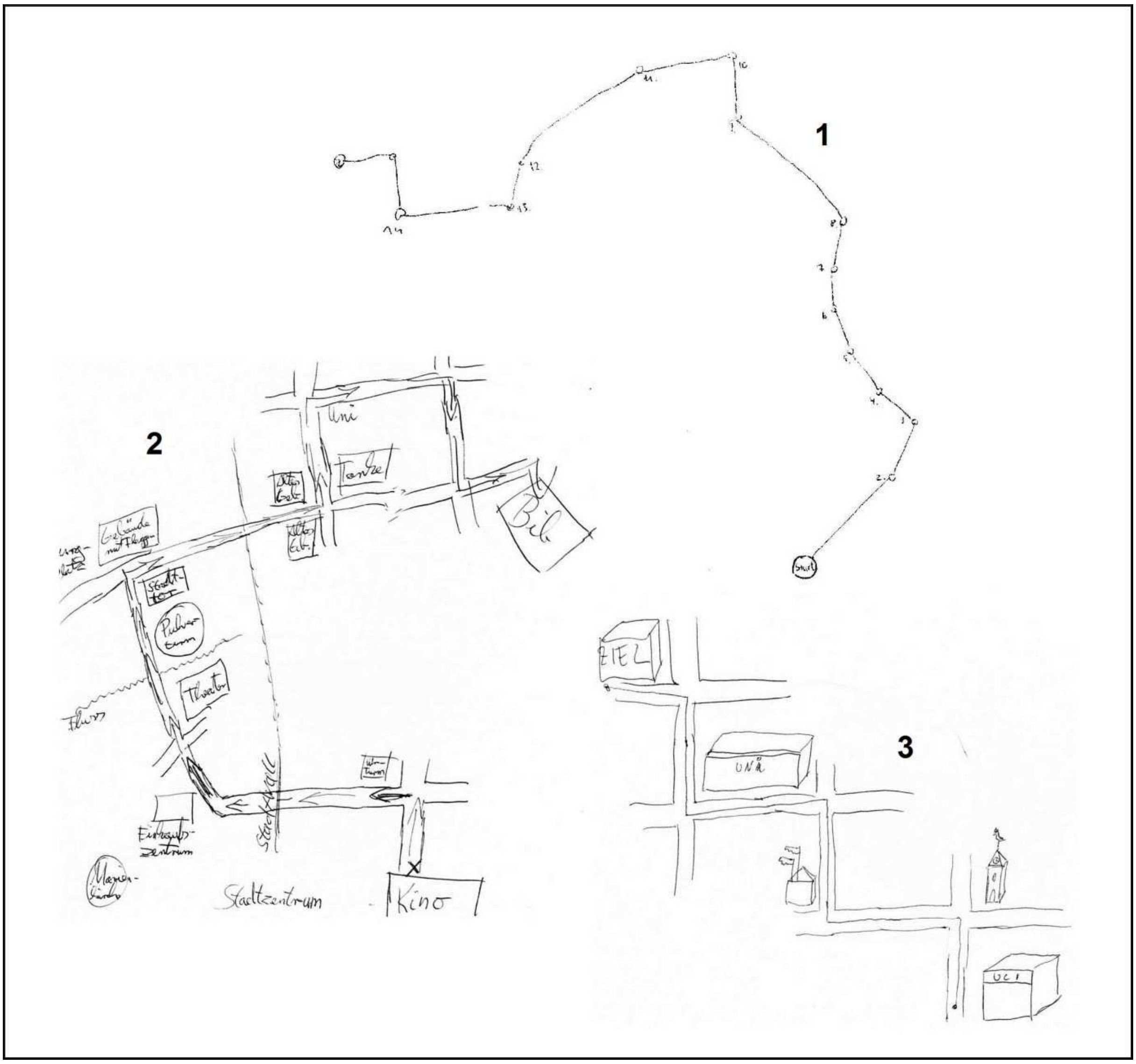


Figure 8: Sketch maps drawn by the participants – example 2.



For the type 1 sketches, it is visible that participants in many cases labeled the route segments with street names, as map 1 in Figure 7 shows. Map 1 in Figure 8, however, demonstrates that some participants (despite this information is missing in the instructions) tried to avoid drawing only straight lines in order to provide a more realistic street layout. This may also be influenced by the fact that the study area has been introduced to the participants as a city with an old town in its center, previously. But what is most striking for sketch maps drawn by participants, who received the machine-generated instruction type, is that in most cases they only contain the route itself, indicated by a sequence of route segments. Thus they resemble routes with few spatial features. Route segments are tended to be considered as straight lines. As intersections and recognizable decision points are not part of this type of instructions, not surprisingly, these sketched maps do not include any landmarks at all. Hence the only drawn spatial entities are streets, except in some cases the origin and the target of the route have been included.

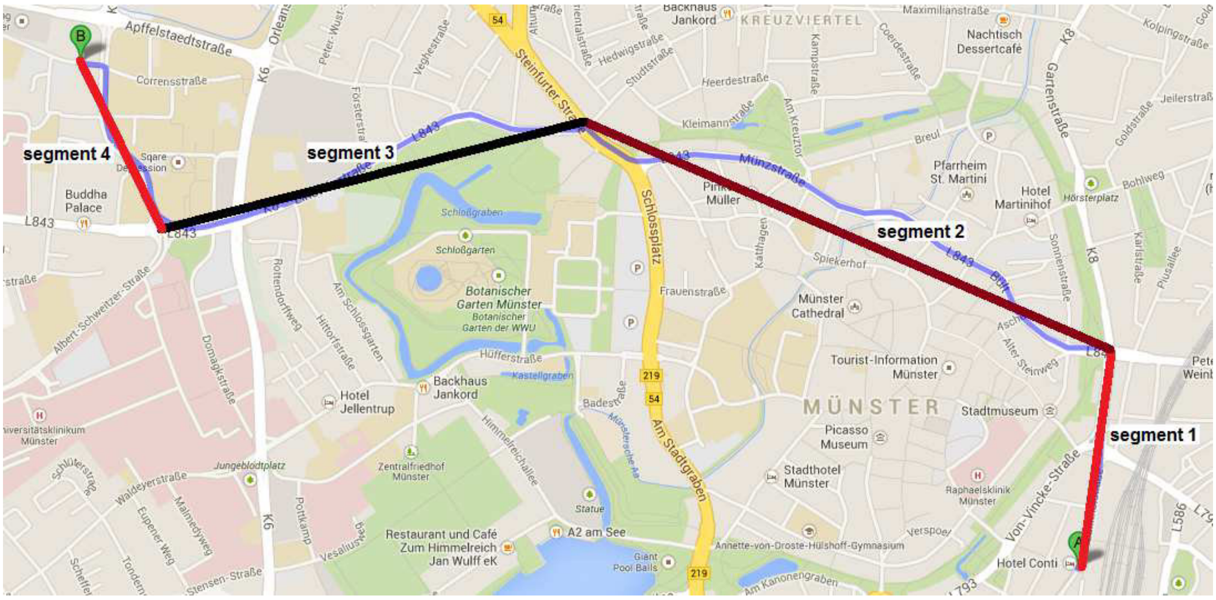
Sketched maps based on orientation instructions however mostly indicate a spatial layout of the area, with not only the actual route drawn, but also intersections and additional street segments. This spatial impression is particularly achieved by including global landmarks in the sketches, like the city center and the Stadtwall, visible in both type 2 sample sketches in Figure 7 and Figure 8. A detailed analysis, if this also results in a more accurate placement of local and global landmarks will be addressed in the following sections. Therefore, it is suggested that orientation-based instructions contribute to higher accuracy in both global and local orientation.

For the skeletal instructions the observation is quite different. These sketches show the least variation, actually in most cases the individual sketches resemble each other in various characteristics, which are discussed later. The most obvious recurring characteristic is the grid-like layout of these sketches. Because the wayfinding instructions include far less landmarks except those at decision points, there were less intersections drawn in this group. Route segments, at first appearance, are mostly drawn by similar length, due to the very limited information content in this type of instructions. Thus, the corresponding sketch maps provide a spatial configuration that is hardly recognizable.

4.3.2 Sketch maps – orientation of route segments

The first approach of analyzing sketch maps included evaluating the hand-drawn maps regarding the orientation of route segments. For this, the original route used in this study has been divided into major sections at nodes where a notable change of direction has occurred. Four route sections have been created so that each section is considered as a straight line from one end node to another. Consequently, the angles between these sections have been measured in degrees. Figure 9 shows the four route sections.

Figure 9: Route sections for analyzing the orientation of route segments.



Source: Google Maps.

The same procedure has been adapted for the corresponding sketch maps of the participants by finding the corresponding nodes in the sketch maps. Consequently, the angles between these sections have also been measured in the sketch maps. Regarding the average deviation values for the route segment orientation, no distinctive differences between the instruction groups have been observed, $F < 1$. Though, it is interesting to note that the average route segment orientation deviation, comprising the sketch maps of all participants, is largest for the orientation-based instructions group ($M = 25.93$, $SD = 12.57$), whereas the route segment orientation has been found most accurate for the skeletal instructions group ($M = 20.80$, $SD = 4.45$). Located in the range between, the machine-generated instructions group reaches an average of ($M = 23.40$, $SD = 18.11$).

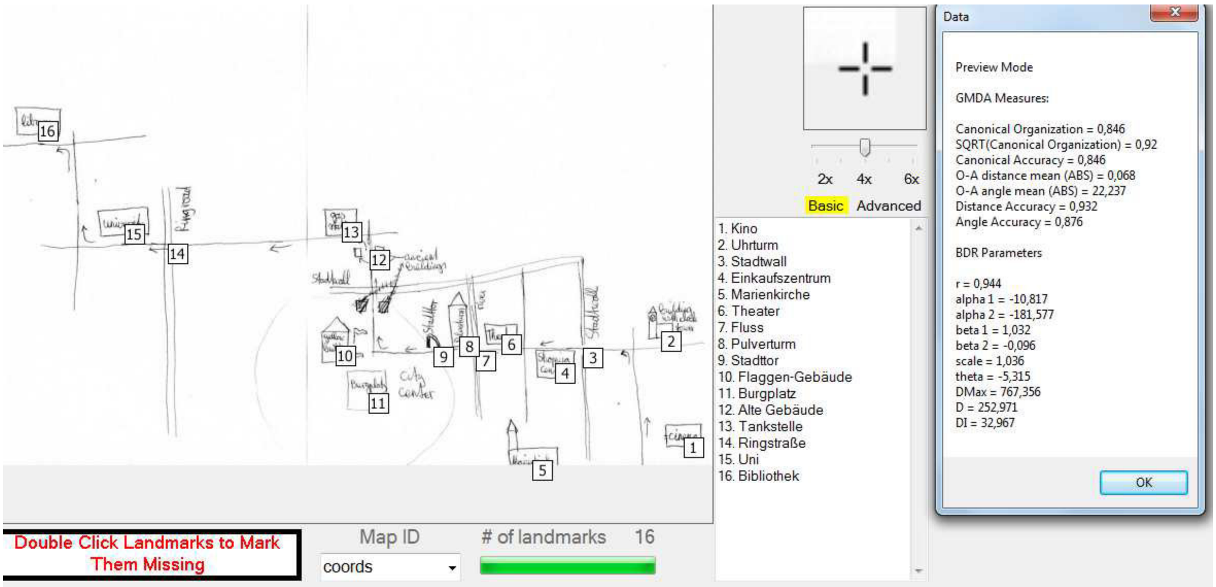
Concerning gender, males ($M = 20.92$, $SD = 10.68$) performed more accurately than females ($M = 26.59$, $SD = 14.78$) regarding the orientation of route sections.

4.3.3 Sketch maps – orientation of landmarks

Besides evaluating sketch maps regarding their orientation of route segments, a further method is to evaluate the placement of landmarks for each sketch map, both categorically and metrically. For these measures, the Gardony Map Drawing Analyzer (GMDA) was used, which has been developed by the researcher Aaron Gardony (Gardony et al., 2013). This software compares the location of landmarks on the hand-drawn sketch maps to the actual Cartesian coordinates of the target environment. Figure

10 provides a screenshot of Gardony Map Drawing Analyzer software. Before loading a map, at first a coordinates file needs to be build. This is done by arranging landmark labels of all landmarks included in the respective instructions onto a map of the real environment. After selecting the matching coordinates file, a sketch map can be loaded for analysis purposes. As visible in the illustration, the landmark labels are then placed at their corresponding positions in the sketch map. So it is possible to compare the location of landmarks in the sketch maps, with their actual location in the real world. As each landmark label is represented by a single point, it is essential to place the top-left corner of each label at the center of its landmark's location. At the right side of Figure 10 a preview of the data measured by the software is shown.

Figure 10: Screenshot of GMDA software.



The categorical measures include the calculation of the canonical organization of landmarks and their canonical accuracy. More specifically, each of the landmarks are compared to all others by examining North vs. south, as well as East vs. West directionality. The difference between canonical organization and canonical accuracy is principally due to the different treatment of missing landmarks. That is, if a participant has omitted landmarks, the score for the canonical organization drops as a result of automatic zero-scoring of missing landmarks. The canonical accuracy, however additionally considers the case that a participant may have omitted some of the landmarks, but accurately arranged those depicted. While canonical organization considers the hand-drawn map in its entirety, canonical accuracy assesses participant’s spatial knowledge of remembered landmarks. Canonical organization is measured by comparing each landmark position relative to all other landmarks drawn in the map by using canonical directions. For this, the software compares observed canonical relationships on the hand-drawn map with the actual arrangement of landmarks within the environment.

While the categorical measures address the relative placement of landmarks, metric measures however evaluate the absolute placement by comparing the placements of the landmarks with the actual environment regarding angle accuracy and distance accuracy. All the measures' scores described range from 0 to 1, with a larger score indicating better results for spatial organization of landmarks, distance accuracy and angle accuracy.

As a cause of the different number of landmarks included in each type of instructions in this study, each type refers to a separately constructed coordinates file. For the orientation based instruction type, the coordinates file includes all 16 landmarks, which are mentioned during the course of the route description. Therefore a marking for each landmark has been placed at their original location on a reference map. The city center has been excluded as a landmark for measurement, because its location is not explicitly named in the instructions and the extent depends on individual judgment. Accordingly, for the skeletal instructions type, the coordinates file consists of only five landmarks, whereas the machine-generated instructions, for comparison purposes, are depicted as a set of six decision points or nodes instead of landmarks. This is because there are no landmarks included, except the origin and the target of the route. Table 5 illustrates the results for all four measures regarding the different instruction types.

Table 5: GMDA measures concerning different instruction types.

Landmark placement	**Canonical organization**		**Canonical accuracy**		**Distance accuracy**		**Angle accuracy**	
Instruction type	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Machine-generated	0.83	0.15	0.83	0.15	0.90	0.05	0.80	0.17
Orientation-based	0.69	0.12	0.75	0.12	0.88	0.04	0.73	0.13
Skeletal	0.89	0.05	0.89	0.05	0.80	0.05	0.85	0.06

Interestingly, results show that angles between landmark combinations are estimated least accurate for the instruction type with included orientation information. Though, due to the accurateness in the direction estimation task for participants of the orientation-based group, this relatively higher inaccuracy in landmark placement seems to have no effect on actual orientation estimation. However, for the skeletal instruction type, angles are estimated most accurately, whereas the machine-generated instruction type reaches an intermediate average value. This negatively correlates with the orientation of route segments (deviation average) investigated in the first approach, $r(28) = -.80$, $p < .001$.

Furthermore the average canonical accuracy for all participants correlates with the average for angle accuracy, with a similar distribution of values concerning different instruction types. Average values for canonical organization only differ from those of the canonical accuracy insofar, as for the orientation-based type the canonical organization value is slightly lower. This is due to the fact that some participants omitted landmarks named in the instructions.

Regarding distance accuracy between landmarks however, results reveal that participants from the orientation based instruction group performed nearly as efficiently as those who received machine-generated instructions. In comparison skeletal instructions though did not lead to an accurate distribution of landmarks regarding distances between them. This coincides with the general observation made prior to the analysis regarding distance accuracy in sketches based on skeletal instructions.

4.4 The role of experience

One of the hypotheses asserted beforehand the conduction of this study refers to a better performance in both the estimation tasks and sketch map accuracy, if a person is experienced in doing wayfinding tasks.

Results however show no significant differences for the direction estimation tasks regarding different experience levels, $F < 1$. Yet, there have been some interesting outcomes worth to be reported. As illustrated in Table 6, surprisingly the average orientation estimation error has been smallest for those participants, who reported to never have done a related task before (experience level 1) and largest for participants, who have done several similar tasks before (level 3).

For the distance estimation error average, this distribution is different. Participants who reported to have done a similar task before (level 2) reached the most accurate results, whereas participants with multiple experiences in comparison performed least accurate.

Table 6: Average direction and distance errors among different experience levels.

	Direction estimation		**Distance estimation**		**Distance accuracy**	
Exp. level	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
1	66.56	27.01	837.41	467.71	0.84	0.07
2	70.56	23.64	575.00	335.29	0.92	0.03
3	82.72	59.84	979.44	467.38	0.87	0.05

Furthermore, regarding the accuracy of landmark placement in sketch maps, a one-way ANOVA revealed that results for distance accuracy have been significant among different levels of experience, $F(2, 27) = 4.60$, $p < .05$. Detailed results for the averages among experience levels revealed that being experienced in performing wayfinding tasks generally leads to a better arrangement of landmarks regarding distances, when drawing a sketch map of a route. Corresponding results are also provided in Table 6.

Furthermore, the relation between experience and sense of direction has been significant (one-way ANOVA), $F(2, 27) = 4.88$, $p < .05$. This indicates that experience in wayfinding could potentially be one factor that contributes to a better sense of direction.

Similarly, a lower level of spatial anxiety is suggested as a result of greater experience in wayfinding, indicated by the results for the different experience levels: Level 1 ($M = 4.07$, $SD = 1.12$), level 2 ($M = 3.25$, $SD = 0.73$), level 3 ($M = 3.38$, $SD = 1.03$).

4.5 Spatial Anxiety

Due to the purpose of measuring the level of anxiety that people would experience in situations that require spatial and navigational skills, the Spatial Anxiety Scale has been developed. The scale consists of eight statements describing spatial situations that are presumed to frequently occur in everyday life. Participants were asked to rate their level of anxiety when facing these situations on a 7-point scale ranging from extremely anxious to not anxious (Hund & Minarik, 2006).

On the contrary to what has been hypothesized beforehand the conduction of this experiment, results reveal that spatial anxiety has no significant influence on both the direction estimation and the distance estimation error, $F < 1$. Moreover, interestingly, participants rated their spatial anxiety the highest in the orientation-based instructions group ($M = 4.31$, $SD = 1.23$), although their estimation error in spatial orientation was the lowest. Participants, who were assigned the machine-generated instructions group ($M = 3.15$, $SD = 0.73$) or the skeletal instructions group ($M = 3.90$, $SD = 0.97$), on average rated themselves less anxious regarding spatial situations.

Furthermore, the performance of participants in the estimation tasks has been evaluated for each instruction group, regarding their level of spatial anxiety. For this, the scores for the spatial anxiety variable have been split up in two groups, with approximately the same number of participants in each group. The mean score of spatial anxiety (3.78) among all participants served as a reference for the splitting. Consequently, the first group comprises of participants with a relatively low spatial anxiety with a score up to the value mentioned above, the second group, accordingly, those who have a higher level of spatial anxiety. The results are illustrated in Table 7.

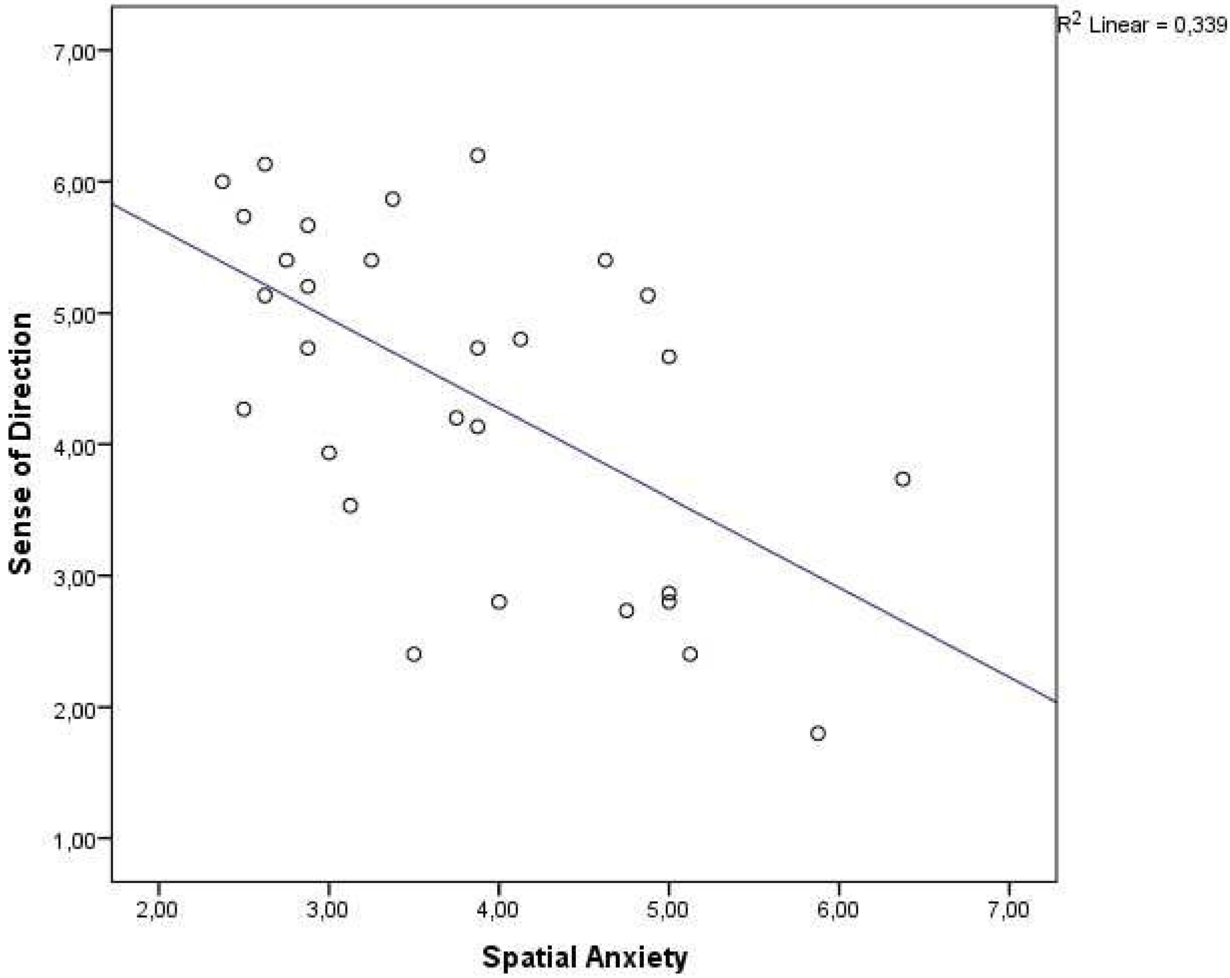
Table 7: Direction estimation error concerning anxiety levels among different instruction types

	Direction estimation error			
	Low anxiety		**Great anxiety**	
Type	**Mean**	**SD**	**Mean**	**SD**
Machine-g.	76.79	27.86	79.83	28.99
Orientation	44.17	12.70	63.21	27.85
Skeletal	72.60	44.83	60.33	27.97

The results provided in Table 7 indicate no distinctive influence of the level of anxiety on direction estimation accuracy for the machine-generated type; as for both anxiety levels, the average deviations are relatively high. However, participants using the orientation-based instructions performed less accurate, when being more anxious. Still, the average value for those participants is comparatively low, since it is lower than the average distance estimation error for all instruction groups combined (*M* = 67.87, *SD* = 29.34). Meanwhile, an interesting observation has been made regarding the skeletal instructions. Here, more anxious participants performed better. Consequently, these results indicate that orientation-based types of route instructions or maybe even skeletal ones can potentially support those people in spatial orientation, who have a great level of spatial anxiety. As results were not significant, for further research a larger sample would be essential to conclude more convincing results that support these assumptions.

Furthermore, spatial anxiety was negatively correlated with the results of the Sense of Direction Scale, $r(28) = -.54$, $p < .01$. Figure 11 illustrates this relationship. Each point in the diagram represents the correlation of spatial anxiety and sense of direction for each participant. It is conspicuous that a lower sense of direction is associated with a high level of spatial anxiety and vice versa. If a low sense of direction is a cause for the development of spatial anxiety, or if spatial anxiety influences human sense of direction abilities remains to be discussed later (Lawton et al., 1996).

Figure 11: Correlation of sense of direction and spatial anxiety scores.



4.6 Sense of Direction Scale

The Santa Barbara Sense of Direction Scale consists of 15 self-referential statements regarding aspects related to spatial cognition (Hegarty et al., 2002), which allow to assess the 'sense of direction' (SOD) of a person. Participants need to respond by circling a number ranging from 1 (strongly agree) to 7 (strongly disagree). Approximately half of the items are stated positively, the other half negatively (Hegarty et al., 2006).

Apart from the results mentioned above concerning the influence of Sense of Direction, regarding the Sense of Direction Scale slightly better results have been observed with increasing age. Hence, the average SOD for age group 1 (*M* = 4.73, *SD* = 1.65) is higher than for age group 2 (*M* = 4.40, *SD* = 1.37). As experience is assumed to increase with age, a connection between this finding and the significant correlation ($r(28) = .37$, $p < .05$) between sense of direction and experience is proposed.

Similarly to the spatial anxiety variable, the scores for sense of direction have been split up in two groups, with approximately the same number of participants in each group. The mean score of sense of direction (4.56) among all participants served as a reference for the splitting. The first group consists of participants with a relatively low sense of direction; the second group those with a higher sense of direction. The results are illustrated in Table 8.

Table 8: Direction estimation error concerning SOD levels among different instruction types

	Direction estimation error			
	Low SOD		**High SOD**	
Type	**Mean**	**SD**	**Mean**	**SD**
Machine-g.	62.58	22.27	78.83	28.73
Orientation	67.43	28.28	43.00	10.63
Skeletal	76.53	43.72	60.90	25.90

As shown in Table 8, results generally indicate that a higher SOD supports spatial orientation and a better performance in wayfinding tasks. For both the orientation-based and the skeletal instructions type it is apparent that the average direction estimation error is lower for participants with a good sense of direction.

However, interestingly, this is not applicable for the machine-generated type. Here, participants did not benefit from a high score in sense of direction, as the average direction estimation error for those participants is distinctively larger than the average error for participants, who reached a low SOD score.

4.7 Spatial abilities

Results further reveal no significant gender differences in spatial abilities, $F < 1$. Though, consistent with a variety of studies (Moore & Johnson, 2008; Halpern, 2011), it is observable that male participants ($M = 4.88$, $SD = 1.41$), on average performed better than female participants ($M = 4.31$, $SD = 1.89$). The influence of gender on spatial perception ability will be further addressed later, when evaluating gender differences in spatial orientation. However, in general, results regarding the performance in spatial ability test have been above average for the participants.

A two-way ANOVA revealed no significant influence of spatial abilities by instruction group on direction estimation accuracy, $F(4, 26) = 1.62$, $p > .05$; however a significant influence has been observed regarding distance accuracy, $F(3, 24) = 8.30$, $p < .01$.

4.8 Self-evaluation of participants

After completing all tasks affiliated with the study, participants were asked to rate their performance on the tasks. A 5-point scale ranging from “very inaccurate” to “very accurate” has been applied to categorize the results. Data evaluation shows that the majority of participants (43.3%) rated themselves as “accurate”, whereas the option “very accurate” has not been chosen by any of the participants. A similar number of participants rated themselves as “inaccurate” (23.3%) or “on average” (26.7%), which leaves 6.7% for those participants, who rated themselves as “very inaccurate”.

Results show that self-evaluation results correlated with those of the Sense of Direction Scale, $r(28) = .36$, $p < .05$. For all results pearson correlations have been used. Participants with a low sense of direction rated themselves generally as inaccurate, whereas participants, who rated themselves as accurate, also reached a higher score for the Sense of Direction Scale (Table 9). But as both variables are based on self-evaluations; this might be a cause of the participants’ confidence regarding spatial situations. Hence these results do not necessarily predict actual performance in the tasks. A similar observation, although not correlated, has been made with respect to spatial anxiety. Accordingly, a low level of spatial anxiety coincides with evaluating oneself as accurate.

Table 9: Averages for the direction estimation error, angle accuracy in sketch maps, SOD and Spatial Anxiety regarding self-rated accuracy.

	Direction estimation		**Angle accuracy**		**Sense of Direction**		**Spatial Anxiety**	
Self-rating	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Inaccurate	63.31	27.48	0.79	0.13	4.41	0.95	4.00	1.42
On average	75.94	32.23	0.81	0.11	4.03	1.24	3.72	1.10
Accurate	63.97	31.79	0.78	0.15	5.21	1.70	3.56	0.80

Table 9 also shows the average values for the direction estimation error and angle accuracy in sketch maps, regarding self-rated accuracy levels. As there were only two participants, who rated themselves as very inaccurate and no participants, who rated themselves as very accurate, these values have not been considered for analysis.

In contrast to expectations, regarding the relationship of self-evaluation and the direction estimation error average, no correlations have been observed. This however indicates that self-estimations do not inevitably imply a certain level of performance in wayfinding tasks. Results from sketch map analysis regarding angle accuracy of landmark placement, which are not significantly different, support this hypothesis.

4.9 Gender differences in Spatial Orientation

Gender differences in human spatial orientation abilities have been widely discussed in literature. Whereas a multitude of studies (Evans, 1980; Harris, 1981; Bryant, 1982), which investigate the influence of gender on spatial abilities and spatial tasks, indicate a better performance of males, in this study no significant differences concerning spatial abilities have been found, $F < 1$. Nevertheless, results show that males (M = 4.86, SD = 1.51) reached a higher average score in the spatial ability test than females (M = 4.31, SD = 1.89). Generally, with respect to the total score of 6 in the spatial ability test, both males and females who participated in this study, performed above average.

Similarly, results from the Spatial Anxiety Scale showed a larger average score for females (M = 4.14, SD = 1.05) than for males (M = 3.48, SD = 1.09), indicating that females rate themselves more anxious than males.

Consistent with the previous mentioned results, a similar observation has been made regarding the participants' results for the Sense of Direction Scale. Based on the results of their self-estimation, male participants (M = 4.84, SD = 1.35) reached a higher score than females (M = 4.10, SD = 1.77), indicating an average better sense of direction for males.

The results of the study may also be influenced by the experience in performing wayfinding tasks. Although not being significant, a conspicuous trend can be observed regarding gender differences in wayfinding experience. For the male participants, 63.3% reported to never have done a task before, which is related to the ones in this study. 20% of the male participants have already done a similar task before, whereas 16.7% have completed similar tasks several times before. For the female participants this distribution is quite different. Whereas the majority of participants (76.9%) reported to never have done such a task before, only 15.4% have done one similar task before and 7.7% remains for those, who completed several similar tasks before.

As already mentioned, a significantly higher distance error for women than for men has been observed. Consistent with previously hypothesized results, Table 10 indicates that male participants further performed better than females in distance estimation among all types of instructions. However, results also reveal more distinctively than previously hypothesized that females may benefit from a potential reliance on route strategies, as they made smaller errors in orientation estimation than males using the machine-generated instructions. In contrast, however, males performed better than females in direction estimation using the orientation-based instruction. Figures 12 and 13 illustrate these results.

Table 10: Gender-related direction and distance errors among all types of instructions.

	Direction error				**Distance error**			
	Male		**Female**		**Male**		**Female**	
Type	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Machine-g.	81.83	30.37	70.75	21.44	489.44	414.17	684.58	313.33
Orientation	54.56	18.71	65.50	31.29	727.78	472.68	1180.67	394.42
Skeletal	65.17	47.13	69.63	24.44	720.00	461.00	1025.00	393.82

Although results were not significant, this supports the assumption that males are supposed to have a better ability to keep track of their own position, which also coincides with the results for the sense of direction scale.

Figure 12: Gender-related differences for direction estimation regarding different instruction types.

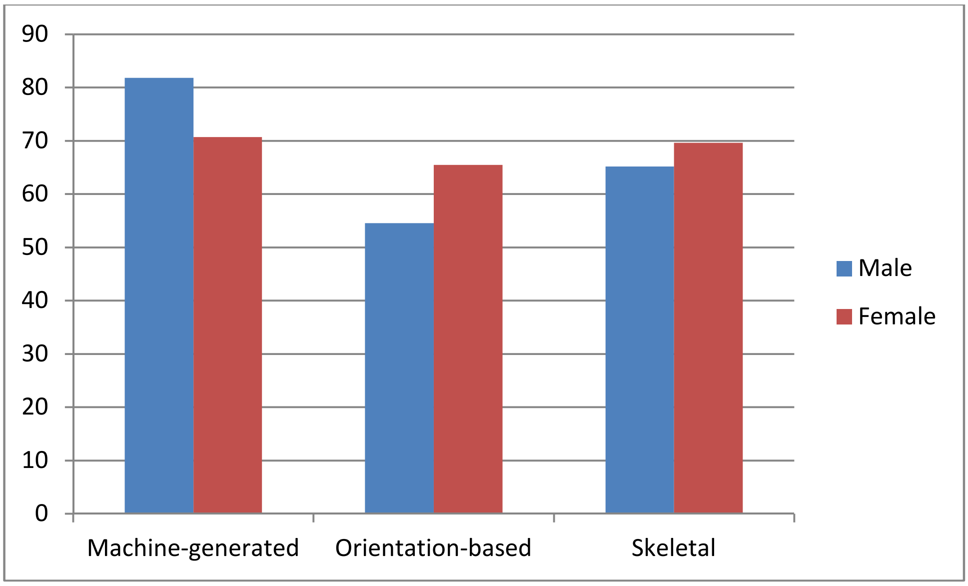
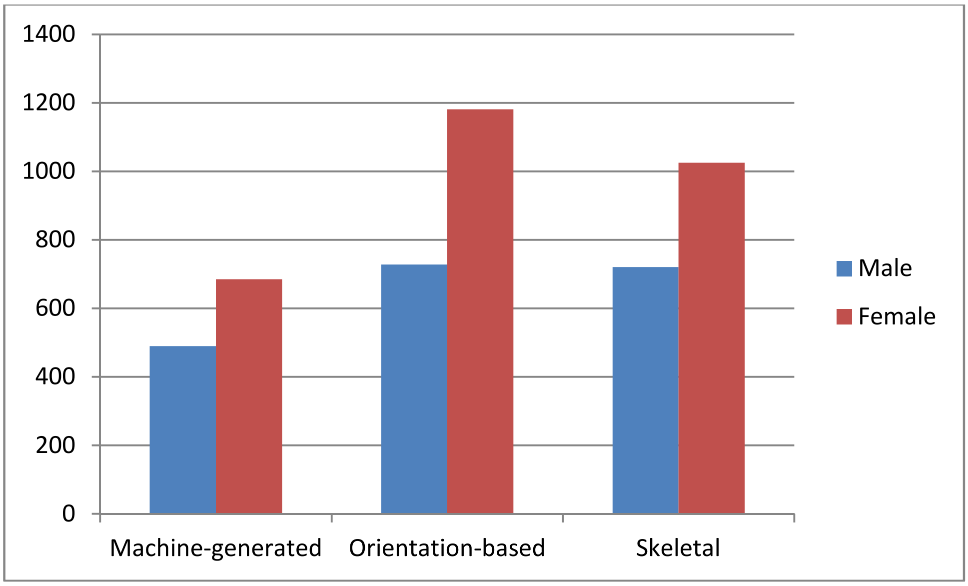


Figure 13: Gender-related differences for distance estimation regarding different instruction types.



4.10 Age-related differences in Spatial Orientation

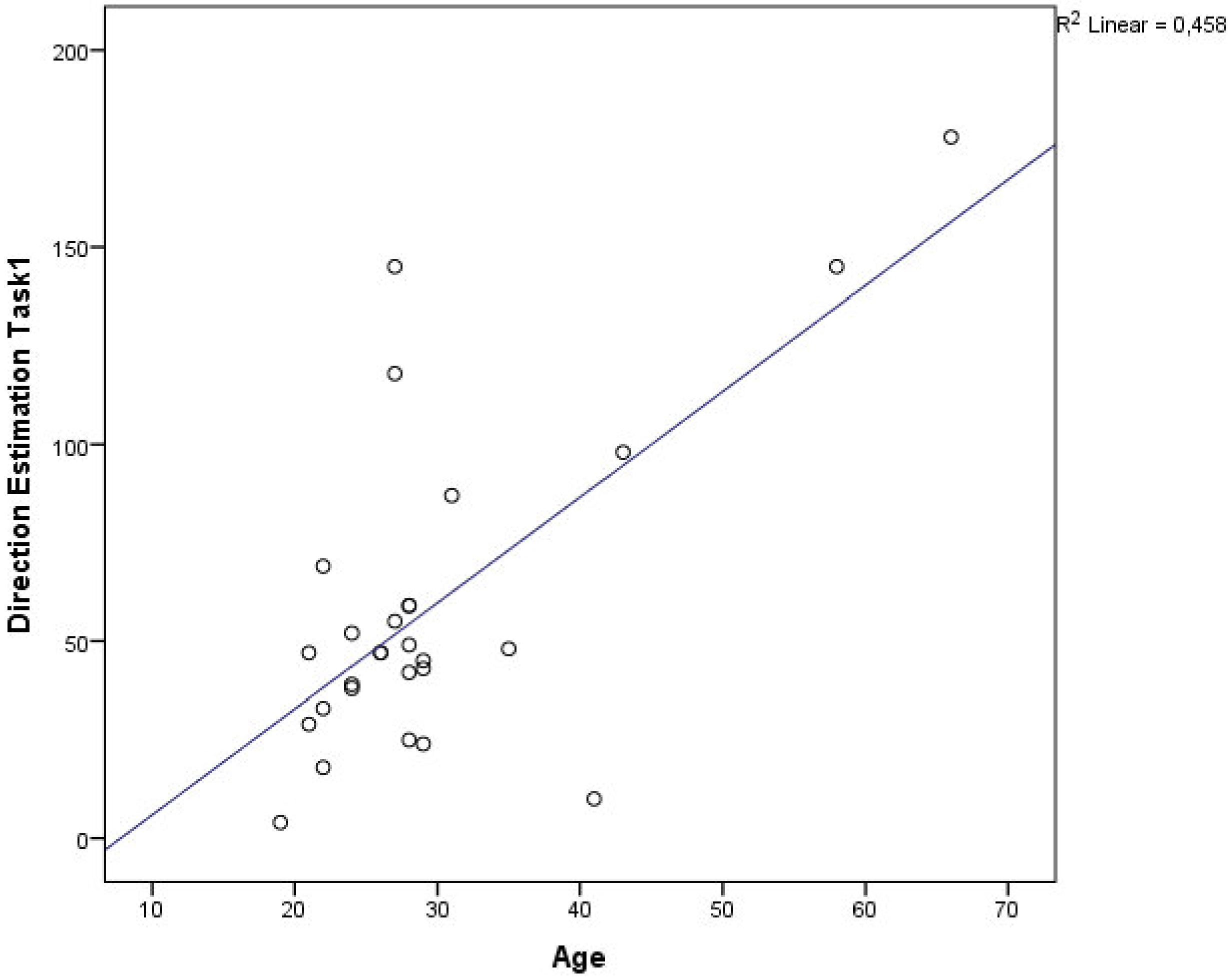
Due to the large variance of the age variable in this study, age-related differences concerning spatial orientation have also been observed. As already mentioned above, the influence of age (based on age groups) on both direction and distance estimation performance has not been found significant. Corresponding values are shown in Table 11. However, the direction estimation average and the original age variable were correlated, $r(26) = .42$, $p < .05$.

Table 11: Average direction and distance estimation errors with respect to the different age groups.

	Direction error		**Distance error**	
Age group	**Mean**	**SD**	**Mean**	**SD**
1	75.40	23.27	491.67	385.05
2	79.40	31.94	643.33	385.05

A more obvious correlation has been observed regarding age and the first subtask of the direction estimation task, $r(26) = .68$, $p < .001$. Figure 14 illustrates this relationship.

Figure 14: Correlation of age with direction estimation task 1.



Regarding self-assessment tasks, consisting of the Sense of Direction Scale and the Spatial Anxiety Scale, no significant differences have been observed, $F < 1$. Although especially spatial anxiety has been presumed to decrease with age, due to a larger amount of experience, such a relationship has not been observed. The same applies for the results of the spatial ability test.

5 Evaluation

Based on the above described results of the experiment, in this chapter these findings will be evaluated more profoundly, particularly with respect to their contribution to spatial orientation.

5.1 The contribution to spatial orientation

As the main purpose of this study is to investigate how the three different types of verbal route instructions contribute to spatial orientation, this section discusses these effects based on the results provided above.

Spatial orientation skills of the participants have been assessed by three different measures: Direction estimation, distance estimation and sketch map drawing. The most important task regarding spatial orientation is the estimation of direction, as here the formation of a first mental representation of the corresponding spatial layout is crucial to achieve accurate results. Regarding the results, as expected beforehand, the orientation-based type has been found most beneficial for direction estimation tasks. This is due to several specific characteristics of the corresponding instructions. More specifically, instructions contain not only local landmarks at decision points, but also landmarks along the route that can potentially support orientation. Furthermore, global landmarks were included to provide an initial idea, how the spatial layout is organized (Winter et al., 2008). Here, especially the city center as a global landmark is important. The other types of instructions did not include this information due to their characteristics, which do not allow including global landmarks. In fact, for those types the biggest challenge regarding the estimation tasks might be developing a spatial configuration, which is not explicitly supported by the instructions. Participants relying on orientation-based instructions, however, had an advantage, because they could use the city center as a reference.

Though as results indicate, surprisingly, this applies not for the first subtask of the orientation estimation task. This particular task included estimating the direction from the target back to the origin of the route, and therefore required knowledge of the entire route. In this context, the good performances of participants using the skeletal instructions might be related to their equally accurate performance in angle accuracy concerning sketch maps.

For the second measure, the distance estimation, results revealed that both the orientation-based and the skeletal instruction did not lead to accurate distance estimations. However, as previously hypothesized, for the machine-generated type distance accuracy has been found most accurate among all types of instructions. Nevertheless, results indicated that the average distance estimation error has still been found relatively high, given that the instructions included distance information in this type. Possible reasons for this might be that participants focused too much on the distances for each segment by adding them together instead of judging distances for the route as a whole, although air distance was required for completing the task. Consequently, it is easier to miscalculate.

As there was no distance information included, for the other types, however, participants were forced to orient themselves on areas similar to the one where the described route is located in. So they could estimate distances for route segments by comparing them to route segments from a known environment. Consequently, by placing the route in a context, it is easier to make out the spatial layout of an area, although this may not lead to accurate distance estimations. In fact, distance estimation has been found most inaccurate for the orientation-based instructions type.

As we can see in the results provided above, this is not reflected in distance accuracy regarding landmark placement in sketch maps. Here the accuracy is similar to those of the machine-generated type. Though in general, as discussed later, the other measures revealed less accurate results regarding sketch map accuracy for the orientation-based type.

As part of the analysis concerning the contribution of different instruction types to spatial orientation, furthermore self-evaluations of the participants have been considered regarding their coincidence with the results.

Regarding the machine-generated instructions type, 40 % of the participants reported the sketching task to be especially difficult, whereas the same number of people (40 %) found this task particularly easy. For the direction estimation task half of the participants (50 %) indicated that this task has been most difficult, whereas only 30 % thought this task has been easy. Concerning distance estimation, 40 % rated this task as particularly difficult, whereas surprisingly, only 10 % reported to have had no difficulties at all in this task. Finally, 20 % reported that no task has been particularly difficult; the same number (20 %) evaluated no task as being particularly easy.

For the orientation-based instructions type, 30 % reported the sketching task to be especially difficult, whereas the same number of people (30 %) found this task especially easy. For the direction estimation task no participants (0 %) indicated that this task has been most difficult, whereas only 30 % thought this task has been easy.

Concerning distance estimation 80 % rated this task as particularly difficult, whereas not surprisingly, no participants reported to have had no difficulties at all in this task. Finally, 10 % reported that no task has been particularly difficult, 50 % that no task has been particularly easy.

Regarding the skeletal instructions type, interestingly, no participants reported the sketching task to be particularly difficult, whereas 80 % found this task especially easy. For the direction estimation, 70 % of the participants indicated that this task has been most difficult, whereas no participants (0 %) thought this task has been easy. Concerning distance estimation this has been exactly the same distribution. Finally, again only 10 % reported that no task has been particularly difficult, whereas 20 % evaluated no task as being particularly easy.

With respect to these self-evaluations provided by the participants, we can conclude that in most cases self-evaluation and actual performance in the wayfinding tasks coincide. However, this does not apply for the machine-generated instructions regarding distance estimation, where only a very small percentage reported to have had no difficulty in judging distances. This may be due to the fact that distances should be estimated as air distance instead of the lengths of route segments. However, not surprisingly, for both of the other types distance estimation has been evaluated as more difficult.

5.2 Sketch maps

When drawing a sketch map of an area that is familiar to a person, unnecessary parts are usually omitted. These sections, however, mostly do not contain relevant information to reach the target of a route. As a consequence, it is suggested that people tend to draw long route segments (which include a change of direction) as distinctively shorter than they are in reality. In the present study, this is especially observable for the skeletal instructions type, where route segments are primarily drawn by similar length, due to missing information about spatial entities along the route.

Landmarks for orientation alongside the route are suggested to be supportive for maintaining spatial orientation. This is also especially important for wayfinders to confirm that the route is still correct. (Schwering & Wang, 2010; Werner et al., 1997). Nevertheless, it has been observed that the accuracy in arranging landmarks has been lowest for the orientation-based instruction type. This may be an effect of the large amount of information, which has been concentrated in a relatively short set of instructions.

An especially interesting finding is that most of the participants of the skeletal instructions group reported to have had no difficulties in the sketching task. As this type of instructions consists only of a minimum set of instructions, previously it has not been assumed to be beneficial for sketching a map of the corresponding route. However accordingly, as mentioned above, results have revealed that sketches based on skeletal instructions reached the highest accuracies regarding route segment analysis, as well as for canonical and angle accuracy of landmark placement. A possible explanation is that the few, but important landmarks in this type are placed more accurately, whereas landmarks, which are not crucial for reaching a goal are placed less accurately (orientation-based type) by the participants.

In contrast to previous expectations, sketch maps based on orientation-based instructions, have not reached high accuracy levels compared to the other instruction types, both regarding route segments analysis and landmark placement. A possible explanation for this finding could be that, although the instructions included detailed information on landmarks facilitating to get awareness of the spatial layout, participants needed to concentrate on keeping the correct sequence of landmarks in mind, making it more difficult to focus on the route itself. Furthermore the total number of landmarks to arrange in the spatial context has been considerably larger for the orientation-based type than for the skeletal type, making it easier to confuse landmark combinations or even omit some of them. This problem has not occurred for the skeletal and the machine-generated type, as they are majorly marked by turn-by-turn characteristics.

However, despite the presumably higher distortions in orientation-based sketch maps, for this type, participants reached the most accurate results in direction estimation among all types. Sketch maps generally serve as externalizations of cognitive maps which in most cases contain distortions and schematic elements (Schwering & Wang, 2010; Tversky, 2002). Depending on the instruction type or the familiarity of a person with the area, sketch maps can also be incomplete. But in most cases they include the information a person thinks is important, omitting irrelevant information (Tversky, 2002). So this suggests that sketch maps do not necessarily need to be accurate, if they contain correct information that is sufficient to provide a spatial layout of the environment. Consequently, sketch maps may be capable of reliably contributing to spatial orientation (Blades, 1990) despite being distorted or inaccurate, as long as the information content is sufficient to provide a survey perspective. As the study area was unknown to the participants, in the context of this study, sketch maps have been drawn according to route instructions instead of a previously developed cognitive map of the participant. So the instructions themselves may be considered as the verbalized content of a potential cognitive map of a person.

To sum up, despite their comparatively high inaccurateness regarding sketch maps, the orientation-based instructions type provided the most accurate results in orientation estimation, making it the most reliable instruction type to support cognitive mapping. For estimating distances, however, the machine-generated instructions type is the most reliable approach, whereas for the skeletal type, both direction and distance estimation has not been found accurate. This instruction type, however, achieved the most accurate results regarding sketch map accuracy, both concerning route segments and landmark placement.

In conclusion, further research still needs to address the construction of efficient wayfinding instructions. Results from this study indicate that using route instructions with included orientation information like local and global landmarks contributes the most to spatial orientation if we consider the results on direction estimation accuracy. However, here some of the participants reported that the instructions may have been too detailed, making it easier to confuse combinations of intersections and landmarks. Therefore it is important, to ensure utmost efficiency in wayfinding and orientation that instructions are constructed detailed, but at the same time clearly stated. Distances however, are not found to be estimated accurately using this type of instructions. Machine-generated and skeletal instructions are not found to lead to good estimations of orientation. They may lead to a route that can efficiently guide a person from an origin to the target of the route, but not contribute enough to spatial orientation, in order to provide a cognitive map of the environment. For achieving more accurate distance estimations in addition to direction accuracy, the inclusion of distance information in the orientation instructions can be suggested. Such instructions, however, would comprise of a too large amount of information, which would presumably be too difficult to process for the participants without resulting in confusion. Consequently, different information provided in the instructions needs to be balanced regarding turn actions, landmarks and optional distance information, in order to construct efficient route instructions.

5.3 The city center as a global landmark

Sometimes landmarks, especially global landmarks cannot just be considered as a point or an object. Especially for the landmark of the city center, it is difficult to determine boundaries, as its shape depends on personal definitions.

This is closely related to the concept of vague places (Montello et al., 2003), implying that due to the way people think and communicate about the environment in terms of vague concepts, some entities are not delimited by sharp boundaries. This particularly applies for indistinct regions like the city center. Generally, the concept of a city center and its boundaries are underlying subjective definitions. That indicates that each individual differently delimits an area denoted as ‘city center’, in some cases this is based on the geographical context (e.g. streets or rivers), frequently attended places like a shopping street or historical aspects (old town). However apparently, most people think that the city center also contains a point of greatest prototypicality, which not necessarily has to be in the center of the representation (Montello et al, 2003).

Although results concerning direction estimation revealed promising directions for further research, there is also the chance that these findings may be influenced by uncertainty regarding the instructions of the task. The major difficulty has been to locate the city center, as it served as a reference point for judging directions for all types of instructions. Although the city center has been mentioned in the orientation-based instructions (in contrast to the other instruction types), its location has not been unambiguously determined, so it has been up to the participant to judge the actual location.

In contrast to the previous mentioned characteristics of global landmarks, in this case the city center inevitably needed to be determined as a single point instead of a region for evaluating the estimation tasks. This is because estimating distances with an area as a reference is challenging, especially with regard to the aim to provide accurate estimations. Therefore, in future studies a more appropriate representation is required.

Thus, to obtain more reliable results, for further research, the reference point for judging direction needs to be determined more clearly.

5.4 Spatial anxiety and orientation

As another important influence on the performance in wayfinding tasks, spatial anxiety has also been considered as a factor in this study.

Consistent with previously conducted research in this field (Lawton, 1994), women reached a higher score in the spatial anxiety test, indicating that women on average would experience more anxiety about environmental navigation than men. Furthermore, in this study a negative correlation between spatial anxiety and sense of direction has been found significant. Similarly, in Lawton's study (1994) results show that spatial anxiety has been negatively correlated to the orientation way-finding strategy, which means that individuals, who prefer to use the orientation wayfinding strategy, are less likely to develop anxiety in situations with a spatial context. In this context, the question arises, how these two factors influence each other. Particularly, there are two possible ways, in which this relationship could be pronounced. Firstly, if a person generally does not maintain a sense of orientation and has not established a cognitive map of an environment, it is more likely to lose orientation and consequently becoming anxious about moving around this environment. Equally, there is also the theory that, regarding a person who feels anxious about getting lost from the start; this anxiety reduces the attention in spatial situations (Lawton, 1994). This attentiveness, however, is crucial for maintaining spatial orientation. Assuming the latter theory is correct, it seems possible that spatial anxiety has the potential to obstruct or even prevent the development of a person’s spatial orientation. This presumption makes it even more substantial to provide ways that may support these individuals in spatial orientation, who report high levels of spatial anxiety. In this present study, indeed, the average orientation estimation error has been lowest for the orientation-based instructions groups, although participants assigned to this group, rated their spatial anxiety the highest. Furthermore, for this type, the average direction estimation error has been comparatively low, even for those participants with a great spatial anxiety. This contradicts with previous findings achieved from a study conducted by Hund & Minarik (2006). Here participants, who reported greater spatial anxiety also made more navigation errors. The findings of the present study indicate that the construction of efficient route instructions, enriched with orientation information can possibly be used to overcome these obstacles as an aid to assist in recognizing the spatial layout of an environment. Consequently, in turn, spatial anxiety can be reduced by this.

Due to its presumed influence on spatial orientation, it is essential to further consider, why spatial anxiety is developing. Could it be related to previously experienced failures in wayfinding or is it exclusively based on different psychological reasons? As results of this study indicate that a lower level of spatial anxiety is associated with greater experience in performing wayfinding tasks, experience could serve as a possible factor, which influences the development of spatial anxiety. Another factor could be related to the age of a person. However in this study, although spatial anxiety has been presumed to decrease with age, due to a larger amount of experience, no such a relationship has been observed. Other studies (Schmitz, 1997) however, suggest that concerning a decrease of spatial anxiety with age, experience could also play a role because it can potentially enhance security, whereas a reduced experience during the early development could support spatial anxiety later on in life. Potential other factors need to be investigated in more detail as part of future research on this topic. This is essential to find ways to reduce spatial anxiety in humans.

5.5 Gender differences in spatial orientation

Regarding this study, distinctive gender differences have been primarily found in distance estimation accuracy. As results show male participants were more accurate than females in distance estimation among all types of instructions. In literature, this distribution is primarily explained by the assumption that males prefer to use Euclidean strategies (Lawton, 1994). Studies on gender-related differences in verbal route descriptions (Brown et al., 1998; Schmitz, 1997) support this hypothesis. These studies emphasize the different aspects females and males refer to, when giving route directions. Therefore, men generally made more use of configurational aspects like cardinal directions and distances in their instructions, whereas women mostly used landmarks to clarify route directions.

In contrast to the significant results obtained in this study, most of the previous studies, which have investigated gender differences in distance estimation, provide no revealing results (Galea & Kimura, 1993; Holding & Holding, 1989). This means that either gender differences have not been observed, or that males outperformed females in route distance estimation. Furthermore, a variety of studies (Galea & Kimura, 1993; Holding & Holding, 1989; Lawton, 1996) has investigated gender-related performance in pointing tasks with respect to direction estimation accuracy. What is most striking is that in most cases, males performed better than females, whereas female performance has never been more accurate than male (Coluccia & Louse, 2004). However, interestingly, this present study indicates no significant gender differences in direction estimation accuracy. Consistent with previously mentioned results from other related studies, slightly better results have been found for males using the orientation-based and the skeletal instructions. For the machine-generated instructions type, however, results revealed better performances for females, suggesting that females may have outperformed males by using this instruction type, because of a potential reliance on route strategies. Due to their better results in direction estimation using orientation-based or skeletal instructions, it seems likely that especially males additionally relied on previously acquired spatial knowledge, instead of navigational support. Concerning the different use of wayfinding strategies, studies (Coluccia & Louse, 2004; Kato & Takeucki, 2003) suggest that successful experiences in situations involving wayfinding tasks can lead to a gain of confidence, assuming that males are generally less dependent on support systems and could shift between different wayfinding strategies. Hence, confidence in the own navigation skills allows a flexibility in strategy choice. Furthermore, Chen et al., (2009) investigated that gender differences between navigational performances are eliminated when guide sign supports were used. This, however, does not apply for map usage, again indicating gender difference in the use of a specific wayfinding strategy. Interestingly, there are also studies which suggest that gender differences can be leveled off, if a survey perspective (by providing maps as navigational aids) is already offered (Coluccia & Louse, 2004). Although not assumed to generally rely on survey strategies for wayfinding, this indicates that females perform better when using a survey representation to support navigation.

Consequently, being hypothesized to approach each other, an interesting extension of the present study could intend to investigate the influences of map usage on direction estimation error averages.

6 Future research

Based on the previously presented results, a promising direction could be observed, indicating that efficiency of wayfinding and spatial orientation can be achieved through orientation-based route instructions. A possible approach to extent this study could address the conduction of the experiment within the actual environment the study refers to. In this case, it would be interesting to examine, if results on actual performance in wayfinding coincide with those presented in this paper. Another issue addresses the area in which the presented route is located, which consists in this case of urban surroundings. Thus, an option would be to adapt the instructions for various different surroundings. These could comprise rural areas, mountain regions or indoor environments.

The conduction of these further steps is presumed to be supportive for achieving a more extensive understanding of the effects of including orientation information in route instructions. So it remains to be investigated, if the results can be generalized for route instructions in different areas, or if the contribution to spatial orientation of each type of instruction varies depending on the surrounding.

Due to the different results concerning accuracy in direction, distance estimation and sketch maps for different instruction types, in a further step this experiment could also be adjusted by conducting it with other participants using these sketches. Thus, the effects on spatial orientation based on the information provided in sketch maps can be investigated in the real environment. Additionally, a possible influence on gender can be addressed.

Finally, future research could address the conduction of long-term studies. These could be used to investigate, if providing orientation information can support those people, who report high levels of spatial anxiety, or if spatial orientation skills can be even improved by using orientation-based instructions.

In addition, conducting this experiment with a larger number of participants is essential to achieve more meaningful and convincing results. Whereas most of the results in this study indicate a definite direction, future research including a larger sample size is required to verify these findings.

7 Conclusion

This study intends to investigate how different types of verbal route instructions contribute to spatial orientation and cognitive mapping. Besides providing instructions that are assumed to be efficient to guide a person along a route like machine-generated and skeletal instructions, the major research goal concerning this study is to construct cognitive efficient wayfinding instructions in the format of verbal descriptions that could potentially facilitate spatial orientation and cognitive mapping. In this context, the previously named instruction types have been compared with instructions containing additional orientation information to support maintaining spatial orientation.

The most important finding is that, as previously hypothesized, all three types of verbal route instructions contribute differently to spatial orientation. In particular, participants who used the orientation-based instructions have been found most accurate in estimating directions, which indicates that participants gained awareness of the respective spatial layout of the environment. Results for the machine-generated and the skeletal instructions type, however, indicate that these types of instructions do not lead to an accurate estimation of orientation. Though, regarding distance estimation, observations are quite different. Despite being supportive for achieving spatial orientation, orientation-based instructions did not lead to accurate distance estimations. For this, not surprisingly, the machine-generated instructions have been found most beneficial. However, results also indicated that, unlike assumed before, the machine-generated instructions with included distance information still pose a challenge for persons to accurately estimate distances along the route. This is marked by a still relatively large distance estimation error.

In contrast to the above mentioned findings for the estimation tasks, results for sketch map analysis indicate that sketches based on orientation information are not found to be accurate, both regarding route segment orientation and landmark placement. The performance on the direction estimation task for this type of instructions, however, shows that sketch maps do not necessarily need to be accurate as long as they are sufficient to provide a spatial layout of the environment.

Further research on this topic includes continuing the conduction of this experiment with more participants, which would lead to more comprehensive and convincing assumptions. In addition, research on this topic also requires investigating the effects of different types of route instructions on actual performance in wayfinding as well as the efforts to address the generation of orientation-based instructions in a more efficient way. For constructing route instructions, which approximate a maximum level of efficiency in their contribution to spatial orientation, several components of different types of instructions need to be combined. These include primarily descriptive elements, which have been found supportive for cognitive mapping (Lovelace, 1999), turn actions as well as local and global landmarks. The inclusion of additional distance estimation for efficient wayfinding instructions still needs to be evaluated.

In conclusion, the results obtained from this study have provided promising direction that efficiency of wayfinding and orientation can be achieved through orientation-based route instructions. Particularly, this type of instructions provided the most accurate results in estimating orientation, which makes it the most reliable instruction type to support spatial orientation and cognitive mapping.

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9 Appendix

Wayfinding instructions type 1

Directions from Hauptstraße to Kopernikusstraße

Hauptstraße (cinema)

1. Head northeast on Hauptstraße toward Goethestraße for 300 m.
2. Continue onto Alleestraße for 270 m.
3. Turn left onto Osttor and drive 120 m.
4. Continue onto Mühlenstraße for 200 m.
5. Continue onto Pulort for 160 m.
6. Continue onto Steingasse for 120 m.
7. Continue onto Kirchstraße for 170 m.
8. Continue onto Sternstraße for 200 m.
9. Continue onto Poststraße for 450 m.
10. Slight right onto Burgplatz, then drive 200 m.
11. Turn left onto Bismarckstraße and drive 350 m.
12. Continue onto Schillerstraße for 650 m.
13. Continue onto Kreuzstraße for 140 m.
14. Turn right onto Robert-Koch-Straße and drive 550 m.
15. Turn left onto Kopernikusstraße.

The destination (entrance of the library) will be on the right after 71 m.

Wayfinding instructions type 2

The route starts in front of the cinema. The entrance of the cinema is on your right. The city center is to your left side.

1. Follow the street in the facing direction until you reach an intersection. You can see a building with a clock tower on the right hand side behind the intersection.

2. Turn left. Shortly after, you cross the Stadtwall.

3. Follow the street in north-west direction. You pass the shopping center on your left hand side and shortly after you reach an intersection, from where you can see the tower of the Marienkirche within the city center to the left. Right after this intersection there is the theatre building on your right. After crossing a small river you pass the Pulverturm, which is on your right side.

4. Go straight on, until you reach a junction, right after you passed a building labeled Stadttor. Straight ahead you see a yellow building with flags in front of it and to the left, there is the Burgplatz.

5. Turn right at the junction. Right after this, you cross the Stadtwall again.

6. Follow the street, and then turn left at the next intersection, right after you passed two ancient buildings on either side of the road. Right after you turned left, there is a gas station on the right side.

7. Follow the street, which is now heading away from city center. You cross the intersection with the ring road that runs around the city. Right after you passed the university main building, which is on the right hand side, you reach an intersection.

8. Here turn right and follow the street until reach an intersection.

9. Turn left. Directly after, you can see a building with a glass facade on the right side, which is the library. The entrance of the building is in your facing direction.

You have reached the target.

Wayfinding instructions type 3

The route starts in front of the cinema.

1. Follow the street until you reach an intersection, from where you can see a building with a clock tower on the right hand side behind the intersection.

2. Turn left.

3. Follow the street and turn right at a junction, from where you can see a yellow building with flags in front of it straight ahead.

4. Turn left at the next intersection.

5. Right after you passed the university main building, which is on the right side, you reach an intersection, where you turn right.

6. Follow the street and turn left at the next intersection. There is the entrance of a glass façade building (library) on the right side.

You have reached the target.

Experimental task

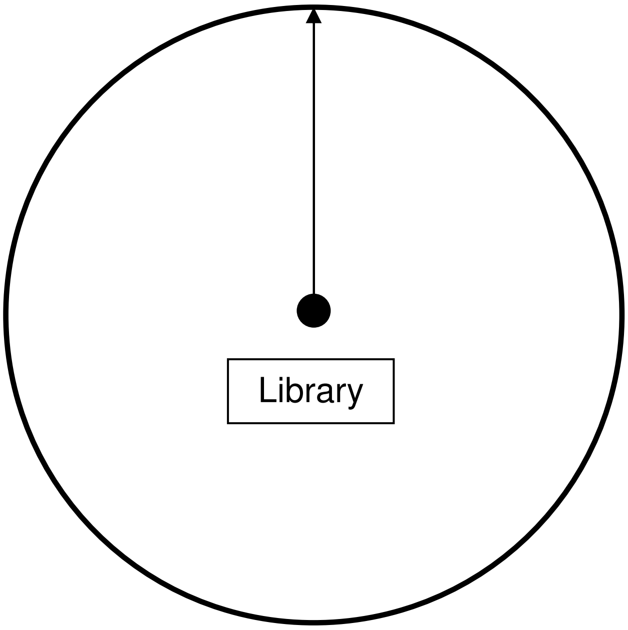
Please complete the following three tasks on both pages.

1) You've reached the target and stand while facing the **city center**.

   Please indicate the direction to the origin of the route by marking on the circle (cinema) and then please estimate the distance between the origin and the target

Direction:

Distance in meter



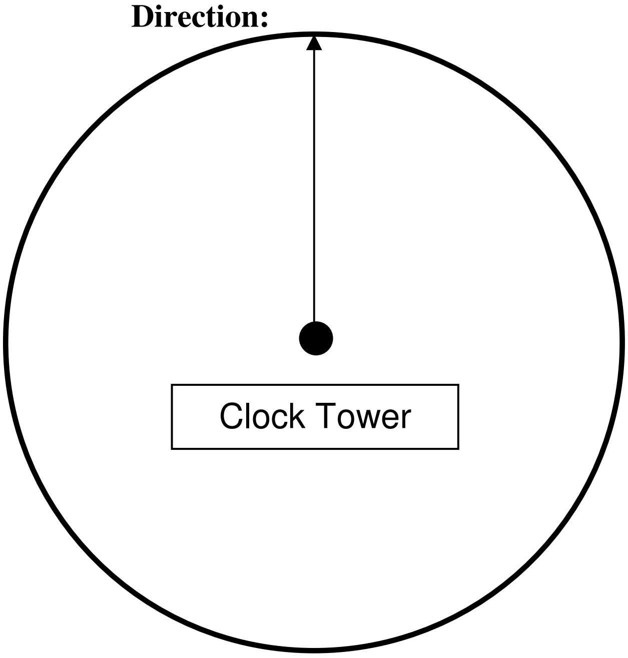
To origin (cinema):

2) You are standing in front of the clock tower (before turning onto 'Osttor') and facing the **city center.**

   Please indicate the direction to the origin (cinema/ Hauptstraße) as well as the direction to the destination (library/Kopernikusstraße) by marking on the circle. Then please estimate the distance between **both** locations by marking on the circle.

Direction:

Distance in meter



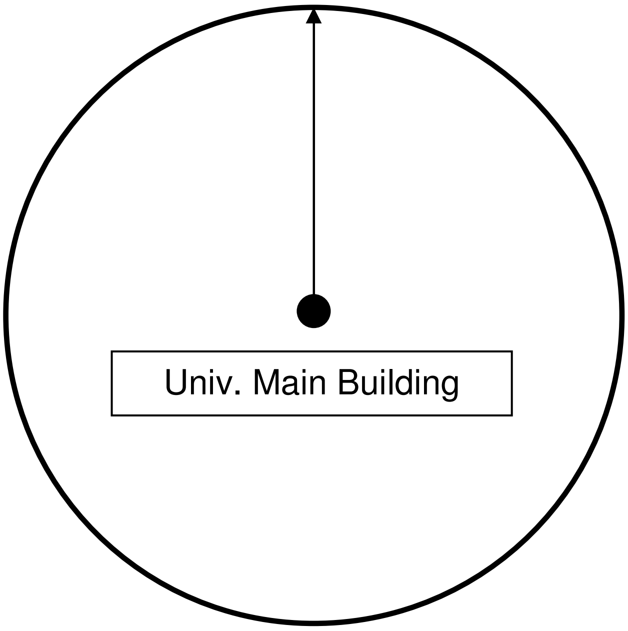
To origin (cinema):

To destination (library):

3) You are standing in front of the university main building (before turning onto 'Robert-Koch-Straße') and facing the **city center**. Please indicate the direction of the origin (cinema/Hauptstraße) as well as the direction of the destination (library/ Kopernikusstraße).

Then please estimate the distance between both positions.

Direction:



Distance in meter

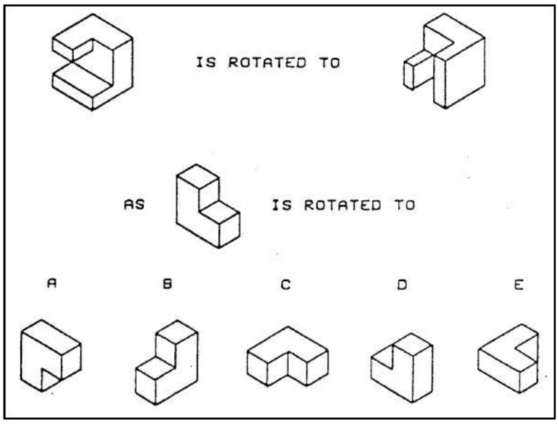
To origin (cinema):

To destination (library):

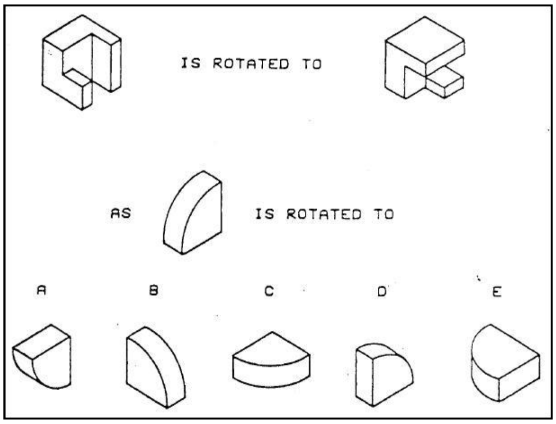
Purdue Spatial Vizualization Test: Rotations

Please mark the answer you think is correct!

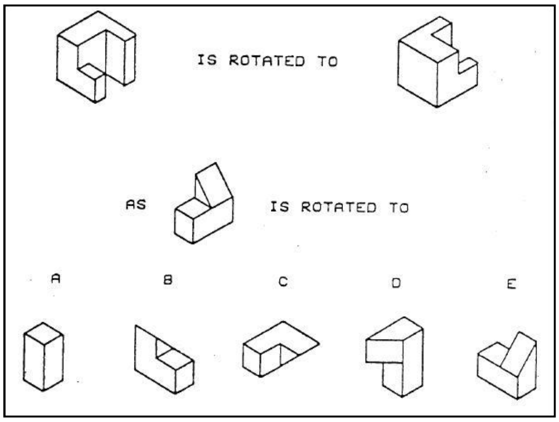
Task 1



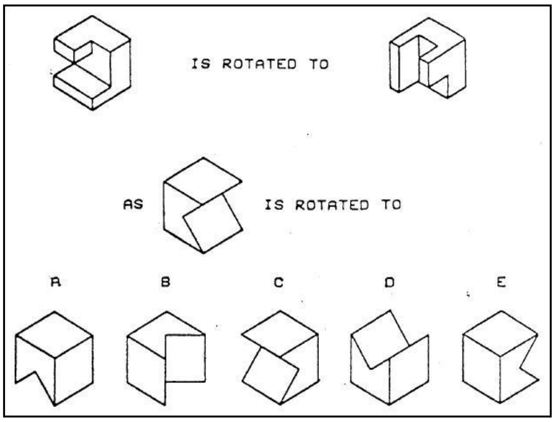
Task 2



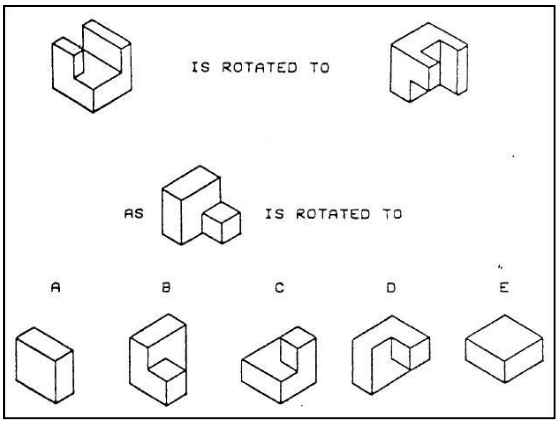
Task 3



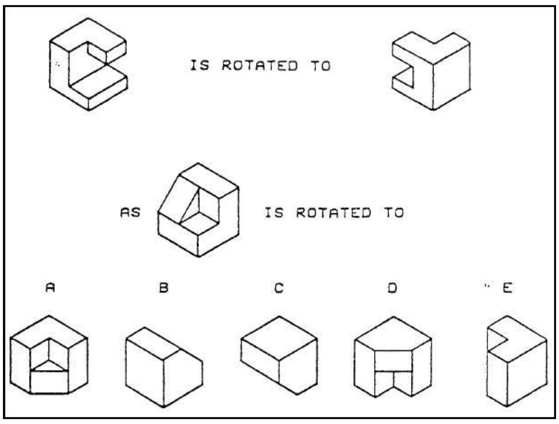
Task 4



Task 5



Task 6



Source: http://www.quiz.biz/quizz-250841.html

SANTA BARBARA SENSE-OF-DIRECTION SCALE

Sex: F M Today's Date:________________

Age:_______ V. 2

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

Questions to reverse code in bold.

1. I am very good at giving directions.

strongly agree 1 2 3 4 5 6 7 strongly disagree

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

strongly agree 1 2 3 4 5 6 7 strongly disagree

3. I am very good at judging distances.

strongly agree 1 2 3 4 5 6 7 strongly disagree

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

strongly agree 1 2 3 4 5 6 7 strongly disagree

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

strongly agree 1 2 3 4 5 6 7 strongly disagree

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

strongly agree 1 2 3 4 5 6 7 strongly disagree

7. I enjoy reading maps.

strongly agree 1 2 3 4 5 6 7 strongly disagree

8. I have trouble understanding directions.

strongly agree 1 2 3 4 5 6 7 strongly disagree

9. I am very good at reading maps.

strongly agree 1 2 3 4 5 6 7 strongly disagree

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

strongly agree 1 2 3 4 5 6 7 strongly disagree

11. I don't enjoy giving directions.

strongly agree 1 2 3 4 5 6 7 strongly disagree

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

strongly agree 1 2 3 4 5 6 7 strongly disagree

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

strongly agree 1 2 3 4 5 6 7 strongly disagree

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

strongly agree 1 2 3 4 5 6 7 strongly disagree

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

strongly agree 1 2 3 4 5 6 7 strongly disagree

Spatial Anxiety Scale

Sex: F M Age: _______ Participant no:______________

This questionnaire consists of several statements about your spatial and navigational situations. After each statement, you should circle a number to indicate your level of anxiety with the statement. Circle "1" if you would feel extremely anxious, "7" if you feel not anxious at all, or some number in between if your agreement is intermediate. Circle "4" if you feel neither anxious nor not anxious.

1. Leaving a store that I have been to fort the first time and deciding which way to turn to get to a destination.

   Extremely Anxious 1 2 3 4 5 6 7 Not Anxious

2. Finding my way out of a complex arrangement of offices that I visit fort the first time.

   Extremely Anxious 1 2 3 4 5 6 7 Not Anxious

3. Pointing in the direction of a place outside that someone wants to get to and has asked me for directions, when I am in a windowless room.

   Extremely Anxious 1 2 3 4 5 6 7 Not Anxious

4. Locating my car in a very large parking lot or parking garage.

   Extremely Anxious 1 2 3 4 5 6 7 Not Anxious

5. Trying a new route that I think will be a shortcut without the benefit of a map.

   Extremely Anxious 1 2 3 4 5 6 7 Not Anxious

6. Finding my way back to a familiar area after realizing I have made a wrong turn and become lost while driving.

   Extremely Anxious 1 2 3 4 5 6 7 Not Anxious

7. Finding my way around in an unfamiliar mall.

   Extremely Anxious 1 2 3 4 5 6 7 Not Anxious

8. Finding my way to an appointment in an area of a city or town with which I am not familiar.

   Extremely Anxious 1 2 3 4 5 6 7 Not Anxious

Please fill in the following information and answer the questions on both sides.

1) Please indicate your age:

___ years

2) Please indicate your gender.

□ Male □ Female

3) How experienced are you in doing wayfinding tasks?

□ I've never done such a task before

□ I've done a similar task, but only once before

□ I've done similar tasks several times before

4) Which task has been particularly difficult for you?

□ Drawing the sketch map

□ The direction estimation tasks

□ The distance estimation tasks

□ None

5) Which task has been particularly easy for you?

□ Drawing the sketch map

□ The direction estimation task

□ The distance estimation task

□ None

6) What do you think, how accurate your work has been?

□ very inaccurate

□ inaccurate

□ on average

□ accurate

□ very accurate

7) If there have been any problems occurred during the experiment, please mention them here.

8) Here you have some space for criticism or suggestions concerning the conduction of the experiment.

Plagiatserklärung der / des Studierenden

Hiermit versichere ich, dass die vorliegende Arbeit über "The effects of different verbal route instructions on spatial orientation" selbstständig verfasst worden ist, dass keine anderen Quellen und Hilfsmittel als die angegebenen benutzt worden sind und dass die Stellen der Arbeit, die anderen Werken – auch elektronischen Medien – dem Wortlaut oder Sinn nach entnommen wurden, auf jeden Fall unter Angabe der Quelle als Entlehnung kenntlich gemacht worden sind.

____

(Datum, Unterschrift)

Ich erkläre mich mit einem Abgleich der Arbeit mit anderen Texten zwecks Auffindung von Übereinstimmungen sowie mit einer zu diesem Zweck vorzunehmenden Speicherung der Arbeit in eine Datenbank einverstanden.

____

(Datum, Unterschrift)