

The effects of different verbal route instructions on spatial orientation

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Abstract

Providing cognitively effective wayfinding instructions is an ongoing research agenda. In addition to providing instructions that are easy to follow, work has started to address instructions that can potentially facilitate spatial orientation and cognitive mapping. In this study, we use a type of verbal instructions that consists of not only landmarks at decision points but also additional landmarks along a route or in distance that are considered crucial for maintaining spatial orientation. The orientation-based route instructions are compared with machine-generated as well as skeletal instructions. Eleven participants were randomly assigned to use one of these three types of instructions to mentally walk a route that they are unfamiliar with and then performed a set of tasks. Preliminary results show that participants using the orientation instructions made fewest errors in their performance of direction estimation. Results from their drawn sketch maps also show more accuracy in global and local orientation. This type of instructions, not surprisingly, does not contribute to accurate estimation of distance. The machine-generated instructions which include distance information, however, are not found contributing to the best estimation of distance. This study supports the potentials of designing wayfinding instructions to facilitate spatial cognition. It also calls the necessity for more comprehensive studies on the effects of instructions on various aspects of wayfinding behaviors, as well as on the automatic generation of orientation-based instructions.

Keywords: Route instructions, landmarks, orientation information, wayfinding, spatial orientation.

1 Introduction

Landmarks are suggested to be crucial in wayfinding instructions to support effective and easy wayfinding as they are indicators of locations in a large-scale environment [1-3]. They have been frequently referred to as decision-making points for reorientation [4]. Studies have shown that constructing wayfinding instructions with local landmarks at decision points lead to more efficient wayfinding [5]. Additionally, research has addressed that landmarks are not only crucial at decision-making points for reorientation [6] but also important along routes for maintaining orientation [7]. We emphasize that cognitively efficient wayfinding instructions should support not only the ease of wayfinding but also spatial orientation during wayfinding. This present study contributes to the understanding of the effects of verbal route instructions including landmarks not only at decision points but also along the route and in distance on spatial orientation and cognitive mapping. In particular, we compare verbal wayfinding instructions including: machine-generated instructions (i.e., Google Maps¹), our designed instructions with landmarks at decision points, along the route, and in distance (orientation-based instructions), and skeletal instructions with landmarks only at decision points [4].

2 Related work

2.1 Role of landmarks

One important role of landmarks is the identification of particular locations [1] as they are discrete objects or scenes against a background that support the easy identification of

locations [2]. Another important role of landmarks is their support for reorientation in wayfinding [4]. Studies have suggested the use of landmarks as a primary or complementary source in wayfinding instructions [3, 8] as they are effective for better outcome such as easier wayfinding guide, fewer wayfinding errors, and shorter wayfinding time [9]. For example, researchers like Tom and Denis [5] compared the use of landmarks in wayfinding instructions with the use of street names. They suggested that using landmarks in wayfinding instructions leads to shorter wayfinding time. Additionally Ross and collaborators [10] found in their study that using landmarks in route instructions leads to less wayfinding errors. In short, the potential of using landmarks in wayfinding instructions is well recognized.

Spatial orientation is also mostly commonly supported by landmarks. As one of important spatial skills, spatial orientation enables persons to be aware of their current locations in relation to destination or other locations in an environment [11]. Wayfinders estimate their locations and relationships between current and other locations in the environment to stay spatially oriented through the use of reference systems [12]. The reference systems could either be egocentric or geocentric [13]. The use of egocentric reference system involves using wayfinders' velocity and acceleration information about their own movement [14], which is less common. 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.

2.2 Location of landmarks

The location of landmarks described in route instructions has intrigued different suggestions in the literature. For example,

¹ <http://maps.google.com>

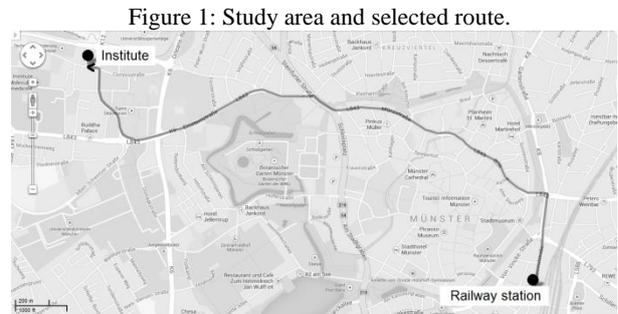
Denis and collaborators [15, 16] suggest that wayfinders often use landmarks for reorientation at decision points where a change of direction is necessary. Therefore, no landmark at decision points would become more difficult for wayfinders to determine the locations where they should change heading directions. Moreover, Lovelace and collaborators [6] suggest that landmarks are not only important at locations where reorientation is needed but also essential at locations where change of direction can be possible (potential decision points). At these potential decision points, wayfinders need to maintain their orientation by continuing the same heading direction. They emphasize that having short wayfinding instructions does not automatically translate into good instructions. Consequently, for achieving short and good verbal instructions, Raubal and Winter [3] suggested the use of local landmarks in wayfinding instructions by providing measures to identify the salience of landmarks 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). Moreover, Richter and Klippel [17] address that the route direction should also be context specific as the structure of the environment is 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 in instructions that are not only at potential decision points but also along the route as well as in distance.

Most of the existing studies introduced above focus on the roles and use of local landmarks that are at potential decision points. Limited studies have addressed the roles of landmarks that are distant from a described route (global landmarks) as those landmarks in distance serves the important role of providing general orientation [18]. Steck and Mallot [19] 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 on a designed route [20]. Based on this suggestion, hierarchical communication of space could be achieved by firstly introducing a prominent global feature in instructions, and then specific instructions to maintain orientation and reach destination. In short, the important role of global landmarks has already been remarked. In this paper, we address the use and the role of global landmarks in verbal wayfinding instructions.

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. The global landmarks is used adapting the hierarchy suggested by Steck and Mallot [19]. 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 the route. This type of instructions is compared with machine-generated and skeletal instructions as used in previous studies (see [4, 21]) to reveal the different effects on performance of spatial orientation and cognitive mapping.

3 Methods

To construct wayfinding instructions of each type, we selected a route within the city where the university is located. The origin is the central railway station and the destination is our institute building. The length of the selected route is approximately 3.9 km (3 km air distance). The study area and the route from the origin to the destination are shown in Figure 1 below.



Source: Google Maps.

Our primary research goal is to investigate the effects of different route descriptions on the performance spatial orientation without the influence of a person’s familiarity with the environment. Therefore, we changed the names of all spatial entities in our verbal descriptions to avoid participants’ familiarity. We introduced the study area as 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 shape as in the original route, while the names of street and other spatial entities were changed in instructions. For example, at the original location, the name of railway station was replaced by the name of a fictional cinema, while at the destination the name of institute building was replaced by the name of a fictional library.

Table 1. Three types of wayfinding instructions for the same route segment used in this study.

Type	Instructions
1. Machine-generated	Turn left onto Bismarck street and drive 350m; Continue onto Schiller street for 650m; Continue onto Kreuz street 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.

Three different types of wayfinding instructions have been constructed. Table 1 provides an example of these three types. The first type consists of machine-generated route instructions

from Google Maps. The second type (orientation-based instructions) provides a route description with landmarks not only at potential decision points based on our previous finding [7]. This type of instructions consists of local landmarks at potential decision points and alongside the route, as well as global landmarks in distance. The third type is constructed according to the skeletal descriptions designed by Denis [16] and used in their later studies [5]. This type of instruction consists of a minimum set of wayfinding instructions with landmarks only at decision points.

3.1 Participants

The study was carried out as a pilot. Eleven participants (Age: $M = 35.09$, $SD = 14.35$; 7 men and 4 women) were recruited. Participants were not exclusively students.

3.2 Procedure

Participants randomly received one type of wayfinding instructions. They were then asked to complete a set of tasks using the wayfinding instruction they received. The first task of the experiment was drawing a sketch map of the described route from the origin to the destination. In the second task, participants were asked to estimate directions and distances at various locations. This task included three subtasks. The first subtask was estimating the direction back from the destination to the origin of the route (facing the same direction) as well as judging the corresponding air distance. In the second and the third subtask, participants needed to mentally change their position to specific landmarks or intersections (depending on the type of wayfinding instructions) on the route and point to the origin and the destination, and then estimate the air distance in between.

To complete the experiment, each participant was asked to fill in two self-rated measures and one spatial ability test including the Santa Barbara sense of direction scale [22], the spatial anxiety scale [23] and the Purdue spatial visualization test for rotations [24].

4 Results

We present the results of our study as follows: 1) direction estimation based on different instructions; 2) distance estimation based on different instructions; 3) sketch maps with respect to route orientation; and 4) the self-rated measures and spatial skills.

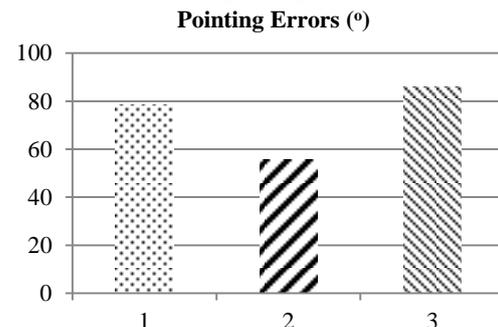
4.1 Estimation of direction

Figure 2 shows the average pointing errors among all groups. Participants using the orientation-based instructions made fewest errors in their estimation of direction ($M = 55.50^\circ$). For the other two instruction groups, the average pointing error are much larger (machine-generated instruction group: $M = 78.67^\circ$; skeletal instructions group: $M = 85.96^\circ$). The orientation-based instructions are the only type that includes the city center as a global landmark. Additionally local landmarks are provided not only at decision points but also along the route. Therefore it seems easier, comparing with the other two types of wayfinding instructions, for participants to mentally arrange the described route into a spatial

configuration. These landmarks (both global and local ones) included in the instructions facilitates the estimation of directions that requires spatial orientation.

As skeletal instructions consist of the least information, the corresponding construction of mental representation seems very limited. This might also be affected by the lack of landmarks, which seems the same regarding the machine-generated instructions. Locations in the environment could not be unambiguously determined based on these types of instructions.

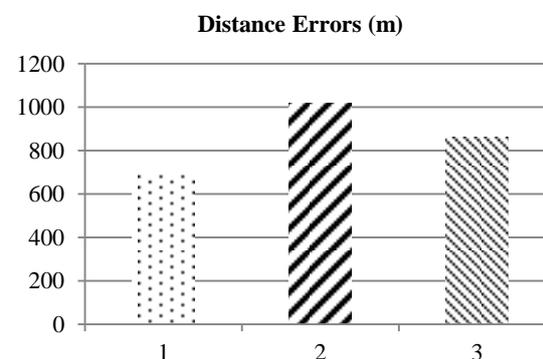
Figure 2. Average pointing errors made by participants among three groups.



4.2 Estimation of distance

As we expected, the distance errors for the machine-generated instructions group are the fewest among all three groups ($M = 691.25m$). These instructions (see Table 1 for example) include distance information for each route segment. However, what we found surprising is that the machine-generated descriptions did not support so accurate estimation, as the average distance errors are still large. Figure 3 shows the average distance errors among all three groups.

Figure 3. Average estimated distance errors made by participants among all three groups.



The distance errors from the skeletal instructions group have been very large ($M = 862.50m$). Interestingly, for participants using this type of instructions, the distances that they estimated were distinctively shorter than those in the other two groups. This is likely due to the limited information provided in the skeletal instructions.

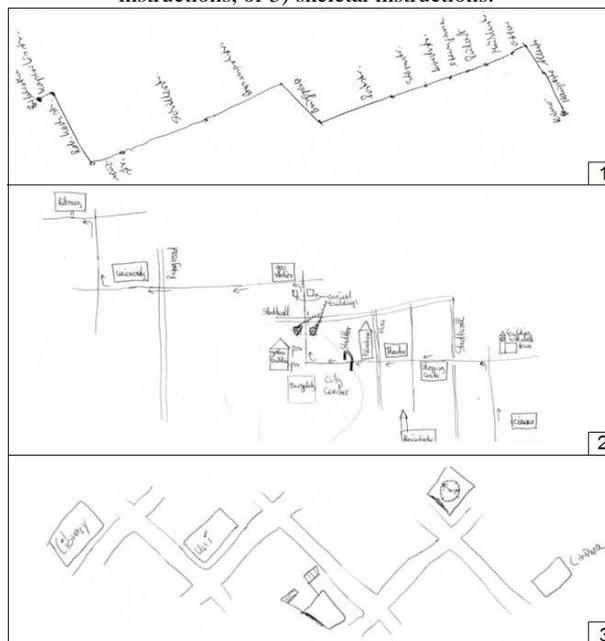
The greatest error was made by participants using the orientation-based instructions ($M = 1016.67m$). It is not surprising as the instructions do not include distance information. What the results confirm is that both global and

local landmarks provided in instructions do not support the acquisition of the specific metric spatial knowledge: distance.

4.3 Sketch maps

We further analyzed the sketch maps drawn by participants in terms of the orientation of route segments. The original route was divided into major segments at decision points where a big change of direction has occurred. In total we created four major route segments. The same procedure has been used for all sketch maps by identifying the corresponding nodes in the sketch maps. Consequently we measured the angles between these segments and compared them with those on the original route. What we noticed is that the orientation of route segments approximately matches the pattern of participants' direction estimation errors. Particularly, the mean angular error in sketch maps from participants using orientated-based instructions is the fewest ($M = 8.56^\circ$) among all three types. However the mean angular errors for the other two types of instructions are much greater (machine-generated instructions group: $M = 17.08^\circ$; skeletal instructions group: $M = 13.58^\circ$). Figure 4 shows the example of a typical sketched map from each group.

Figure 4. Sample sketch maps drawn by participants using 1) machine-generated instructions, 2) orientation-based instructions, or 3) skeletal instructions.



We also measured the length of each route segment within each sketch maps. Unlike the actual distances of the route segments that vary, participants using skeletal instructions drew each route segment with a very similar length (map 3 in Figure 4). This is primarily due to the very limited information given in this type of instruction that participants were unable to derive distance from the instructions.

In the orientation-based instructions group, the lengths of drawn route segments are more accurate than those in the skeletal instructions group (map 2 in Figure 4). Participants

used the described landmarks as references in drawing. It is important to note that sketch maps from this group show different lengths for route segments, which are more accurate than those from the skeletal instructions group. Participants using orientation-based instructions, however, made the greatest error in distance estimation.

In the machine-generated instructions group, the lengths of route segments are relatively more accurate than both other groups (map 1 in Figure 4). As the instructions provide distance information for each segment, participants are likely to draw sketch maps based on this information. This also explains the linear appearance in sketch maps, as well as the fewest errors in their distance estimation task.

4.4 Self-rated measure and spatial skills

The average score of the sense of direction scale (SOD) does not show significant differences among all three groups: 5.20 for participants using machine-generated instructions, 4.42 for participants using orientation-based information, and 4.38 for participants using skeletal descriptions. Regarding the scale of spatial anxiety, participants in the orientation-based instruction group had the highest level of spatial anxiety (4.42), whereas participants in machine-generated instruction group and skeletal description groups have slightly lower spatial anxiety (2.67 and 3.90, respectively). It is interesting to note that participants rated their spatial anxiety the highest in the orientation-based instruction group, but their performance in tasks was not the worst among all three groups. Whether this type of wayfinding instructions can support those who have great spatial anxiety will be further addressed in our ongoing studies.

The score of mental rotation test shows that the participants generally had similar spatial abilities (4.5 for machine-generated instruction group; 5 for orientation-based instruction group; and 4.75 for skeletal description group). Here we only present the descriptive statistics of participants' scores to indicate that participants do not represent great differences among groups. With the involvement of more participants in our continuing study, we intend to investigate the association between these measures and participants' performance using different types of wayfinding instructions.

5 Discussion

5.1 The effects on spatial orientation

As the machine-generated instructions only include distances and street names, it is not surprising that the distance estimation is more accurate than the direction estimation. The biggest challenge for this type of instructions is the acquisition of spatial configuration, as it is not supported by the turn-by-turn instructions. For the skeletal instructions group, it is also very apparent that both distance and direction estimation tasks are difficult, as very limited information is provided. Furthermore, little information with landmarks only at decision points seems to imply short distance for each route segment. This type of route instructions may efficiently guide a person from the start point to the destination, but may not greatly contribute to the person's spatial orientation. For the orientation-based instructions, however, persons are provided with additional landmarks along and distant to the route.

These described landmarks provide confirmation information for guiding a person to reach the destination. Furthermore our preliminary results show the potential of using landmarks that are along a route (local) or in distance (global) to support spatial orientation with directions. Yet this does not lead to accurate estimation of distance.

5.2 Sketch maps

Participants using the machine-generated wayfinding instructions drew sketched maps with very few spatial features. Route segments are most drawn as straight lines. This is primarily caused by the turn-by-turn characteristics of machine-generated instructions. As intersections are not described in this type of instructions, not surprisingly, these sketched maps do not include any spatial entities except streets. Sketched maps based on orientation-based instructions show a spatial configuration of the area in addition to the route described. Additional street segments and more accurate placement of local and global landmarks are also included in sketch maps of this type. It seems that described global landmarks and local landmarks facilitate the acquisition of spatial configuration. Sketch maps based on the skeletal instructions are quite different. Because the wayfinding instructions include landmarks only at decision points, there are fewer intersections drawn on sketch maps. More so, the drawn sketched maps provide a spatial configuration that is hardly recognizable. Therefore, we suggest that providing wayfinding instructions with global landmarks and local landmarks (at decision points and along the route) contribute to cognitive mapping efficiently that a person can acquire reasonable spatial configuration.

6 Conclusion

Besides generating instructions that are easy to follow, our major research interest is addressing cognitively efficient wayfinding instructions that can also facilitate spatial orientation and cognitive mapping. In this study, we investigate the roles of different types of verbal wayfinding instructions on spatial orientation and cognitive mapping.

The most important finding is that including global and local landmarks in route instructions contributes to spatial orientation and cognitive mapping. Landmarks located in distance, at potential decision points, and along a route help a person to acquire reasonable spatial configuration of an environment. This acquired spatial configuration consequently helps a person to better orient in an environment. Despite its supportive role on spatial orientation, this type of instructions does not lead to accurate acquisition of distance information.

Unlike what we previously assumed, the machine-generated instructions, which include distance information for each segment, still remain challenging for a person to acquire spatial knowledge about distance among features in an environment.

Due to the preliminary status of our study, we have not addressed the effects of different types of route instructions on actual wayfinding performance. The results here have provided us promising information that efficiency of wayfinding, spatial orientation and cognitive mapping can be achieved through including global and local landmarks at

various locations in route instructions. We are conducting this study with a larger number of participants, which would lead us to a more comprehensive understanding. This study also raises questions including the investigation of the effects of route instructions given in different formats such as map, as well as the generation of orientation-based instructions in an efficient and automatic way. These are the logical follow-ups for us to address in future studies.

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