Navigating on web maps: Route characteristics and performance

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Abstract

Providing spatial information by using maps has been developed into a widely accepted means for supporting wayfinding. While most studies focus on the effects of actual wayfinding performance, this study investigates how different route characteristics affect the interactions and wayfinding on online maps. These characteristics are assessed by constructing verbal route descriptions in three different conditions: 1) allocentric, 2) egocentric, and 3) landmark-based. In total 22 participants were randomly assigned to navigate using all three conditions of instructions to find waypoints on routes with the similar complexity and length. Preliminary results reveal that participants with lower spatial abilities took significantly longer time to complete the navigation tasks than those with higher spatial ability. Furthermore, using allocentric route instructions, participants took less time in finding the waypoints than those using landmark-based instructions. Additionally, interactions such as zooming were found associated with the instruction type. In particular, these findings are slightly different from previous studies carried out in actual environment indicating that landmark-based route instructions are most supportive for actual wayfinding and spatial orientation. When using and interacting directly with maps, however, instructions provided through an egocentric or landmark-based frame, require participants to transfer their acquired egocentric frame of reference to an allocentric frame as represented in maps. In other words, when acquiring spatial knowledge in environment for actual wayfinding tasks, there is no change in the frame of reference (egocentric or landmark-based). Hence landmarks serve an efficient role in actual wayfinding. To sum up, the preliminary results of this study contribute to clarifying the roles of different route instructions on wayfinding tasks on web maps.

Keywords: Route characteristics, frame of reference, wayfinding, spatial learning.

1 Introduction

Maps play a crucial role in providing spatial information for persons to learn about an environment. Especially to someone who is in a new environment, maps have been used as reliable sources to provide support for wayfinding. Nowadays, the use of maps has been increasingly shifted from paper maps to web maps either on computers or on mobile phones.

Wayfinding is one of the most common activities performed by humans on a daily basis. Maps—in various formats—are the most commonly used forms of external representations to plan routes from origins to destinations and then to follow a particular route. Maps as a source for spatial information have long been an approved means for wayfinding [1]. Maps also serve as a cognitive interface to connect a person's internal spatial representations of the outside world and external environments [2]. Thus, map designs should consider the characteristics of internal representations, which are often referred to as cognitive maps [3-5], so that it is easy for people to establish the correspondence between map symbols and real-world entities. The construction of cognitive maps relies on various types of spatial knowledge.

Based on the way how a person acquires spatial knowledge, the acquired spatial knowledge may be constructed in different frames of reference. For example, researchers like Levinson [6] suggested frames of reference including *intrinsic*, *relative*, and *absolute* types. Later Klatzky [7] suggested *allocentric* and *egocentric* frames of reference which are also widely referred to nowadays. People can shift between different levels of spatial knowledge [8] as well as frames of reference. Researchers have investigated the impacts when changing frames of reference on wayfinding performance in actual environments [9] as well as the sex-related differences in preference of frame of reference [10]. It is of our interests in this study to further clarify the role of frames of references on wayfinding tasks that are not in the actual environment but in web environments.

1.1 Spatial Learning

Cognitive maps refer how spatial knowledge is stored and structured mentally [3]. A person's cognitive map concerns her location in space, the destination of her movement, the way she reaches the destination and how she communicates with others about space. To interact with space, people need to integrate different forms of spatial knowledge into a common cognitive map [11]. In the real world, people can obtain landmark and route knowledge through visual and physical exploration, but the primary resources for configuration knowledge are maps which are regarded as external artifacts of geographic knowledge acquisition and as cognitive interfaces to external environments [2].

1.2 Map factors

Many research efforts have been made to address the effectiveness of different map designs on the understanding of map information and acquisition of spatial knowledge. One of the most prominent examples is the research conducted on You-Are-Here (YAH) maps. YAH maps represent the layout and the location of a certain area from an immovable viewpoint (map is attached to a wall or an otherwise permanent structure). For travelers who are visiting a place for the first time, the YAH map will be an important navigational aid for finding their way. Levine [12] was the first who detailed cognitive aspects of YAH map interpretation and clarified the principles of YAH maps in a later article [13]. There are two principles of YAH maps in consideration. The first one is the *alignment aspect,* which states that the alignment of objects on maps should be in the same alignment on the terrain. The second consideration is the *forward-equivalence* consideration, which describes that in human's cognitive manner the up area of the map refers to the forward facing direction. People who learn the environment from the YAH map obeying the two principles are suggested to solve wayfinding tasks more efficiently and with higher accuracy than those who acquired their knowledge from misplaced and/or misaligned YAH map [14, 15]. The orientation-specific manner of map viewers played a very crucial part in the wayfinding performance.

1.3 Route characteristics

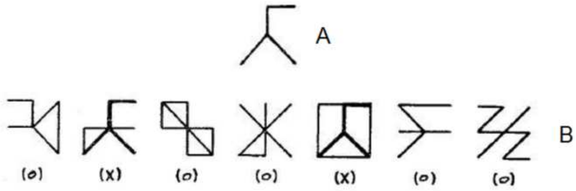
While factors of map design have been widely discussed, it is limited in research addressing the effects of instructions supplementing a map for wayfinding. For example, most online routing services (e.g. Google Maps, MapQuest, or Bing Maps) provide driving or walking instructions in use of street names and distance in an allocentric or egocentric frame of reference. Research has indicated that frames of reference impact on acquisition of spatial knowledge and wayfinding performance in actual environments such as changing frames of reference [9] or sex-related preference to frame of reference [10]. It is of interest to us to extend these acknowledged suggestions to different environments such as computer environments as web maps are widely used in our daily lives. When these web maps present route instructions, it remains to be investigated, how these route instructions would affect a person's acquisition of spatial knowledge and learning of this route in the web maps. Based on the literature, we designed three different frames of reference including allocentric, egocentric, and landmark-based instructions to describe routes using the same map factors for assessing their influences on the accuracy of performance and interactions on web maps.

2 Methods

This study consists of two different series of tasks. The first series assesses the spatial abilities of the participants, while the second series assesses performance in web map-based navigation tasks.

The first task was a hidden figure test that examines if a person is able to recognize a figure that is hidden among other structures (consisting of an arrangement of lines). The used Hidden Pattern Test [16] consists of two parts. Each part contains two pages including 100 items. Given a previously specified figure (the same for both parts), participants were asked to identify as fast as possible, if the figure is contained. Furthermore, both parts needed to be completed separately, for each given a time limit of 3 minutes. Figure 1 shows the reference figure (A) and below a selection of seven different options (B), which can possibly contain this figure. It has been essential for this test to also mark the options, which do not contain the figure in order to delimit the case that a participant left out some options. Furthermore, the orientation of the reference figure needed to be maintained. That is, the person could not mentally rotate or mirror the reference figure.

Figure 1: Sample task of the Hidden Pattern Test.



The second series of tasks aims to investigate the influences of different frames of reference on performance and map interactions, when the participant is navigating through an unfamiliar environment online. The instructions of three routes, which share similar complexity and length, have been provided through an allocentric, an egocentric and a landmark-based frame. In particular, route instructions provided in an allocentric way concern the spatial configuration of an environment including cardinal directions and distance information. Egocentric instructions, differently, refer to a person's current location by giving directions (e.g. 'left' or 'right') that are directly attached to the viewing direction. Landmark-based instructions refer to significant objects, which are located either at decision-making points, or off route to provide anchoring points along the route [17, 18]. The instructions were given in German. Table 1 provides a translated example of three different instruction types. The instructions each refer to a path starting from the previously found waypoint to the next waypoint that needs to be found.

Table 1: Sample instructions describing the same route segment in all of the three conditions.

Type	Instructions
Allocentric	Walk 300 meters in northwest direction until you reach an intersection with a footpath.
Egocentric	Walk 300 meters to the right until you reach an intersection with a footpath.
Landmark-based	Exit the roundabout between the schools and walk in the direction of the town hall until you reach a footpath behind the railroad crossing.

For testing performance by using these different route instructions on web maps, the "OriGami" (Orientation Gaming) application [19] was adapted from an earlier mobile edition to a desktop edition. In the editor view, a new route can be created by adding waypoints to the map and providing verbal instructions for reaching each waypoint. The interface of the test consists of a simple base map (Open Street Map) and route instructions will display at the bottom of the screen once a previously created route is loaded.

At the beginning of the test, the origin of a route needs to be located, which is visualized by a small green flag. Afterwards a participant is asked to locate the next waypoints according to the provided route instructions, until the destination is reached.

A participant locates a waypoint at a specific location by clicking on the map. Immediately after doing so, a circle appears around this location, which indicates a buffered zone of acceptance. If the actual waypoint is located within this buffer, the waypoint is indicated as "found" and the test continues with the next instruction of the route description. Otherwise the participant needs to try again. Furthermore, the buffer around the estimated location of waypoints is static. This means that it does not grow when zooming out of the map, but rather keeps the absolute measure of its radius.

In addition to the use of texts to indicate the accuracy of locating waypoints, a smiley was also used in this test to provide visual feedbacks. A smiling green face in the upper right corner of the map indicates that the waypoint has been successfully found, together with a remark announcing this success. In case a waypoint has not been found, the icon shows a red unhappy expression. In this case, the participant again needs to estimate the location until the waypoint has been found, which results into a learning effect. Furthermore, the shades of red indicate the distance between the located waypoint and its actual location. The darker the shade of red is, the further away the located waypoint is from its real location.

Participants can decide freely for a suitable zoom level to navigate along the route, using the provided instructions. For each click on the map to indicate a waypoint, the current zoom level is recorded. This information can help us find out if the choice of the zoom level is related to the characteristics of the route instruction. A zoom level of 19, for example, indicates that a participant zooms in to the maximum zoom level displaying the smallest area with the most details. Adjusting zoom levels is useful in most cases, as some objects, which are part of the instructions, are only visible at higher zoom levels.

Figure 2 illustrates a screenshot of the OriGami test in the browser version. In the middle of the screen the recent waypoint is visible within the circle. Together with the smiley, this indicates that a waypoint has been found. The instructions displayed at the bottom of the map always refer to the next waypoint, which needs to be found.

2.1 Participants

In total 22 participants have been recruited so far to take part in the experiment (18 men and 4 women; Age: *M* = 27.61, *SD* = 4.77 for men and *M* = 26.25, *SD* = 4.92 for women). The majority of the participants were students at the author's university.

Figure 2: Screenshot of a route following task using OriGami. Instruction in German indicates a route described in landmark-based frame: *To your right you see the sacred heart church, to your left the old post office. Walk to the next intersection*.

2.2 Procedure

Participants were asked to complete the Hidden Pattern Test first, and then navigate in the OriGami tests. They were asked to navigate along three different routes according to the provided route instructions. All participants completed these tasks in all of the three instruction conditions (allocentric, egocentric and landmark-based). The order of the instruction conditions was counter balanced among participants. The experiment took about 30 minutes per participant.

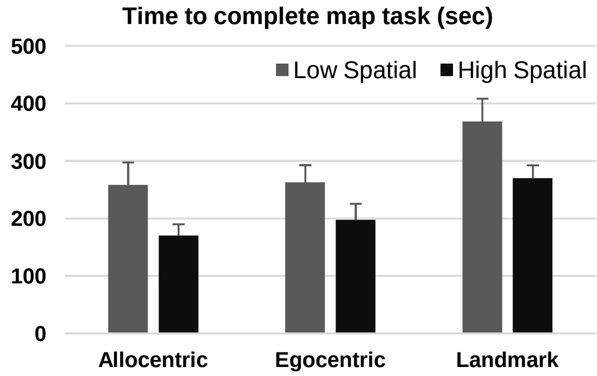
3 Results

The collected data contain the following items regarding each of the instruction types: 1) the time (sec) that a participant used to complete the OriGami test, 2) accuracy of clicks based on the total number of clicks and false clicks, and 3) the maximum zoom level used for completing the task.

We applied repeated ANOVA in our assessments of these data. Recorded data such as time used by a participant, accuracy, and interactions such as zooming were entered respectively as the dependent variable, while the instruction type was entered as a within-subject variable and spatial abilities using a median split on participants' hidden pattern test score was entered as a between-subject variable.

When entering time of completing tasks in each instruction condition as the dependent variable, we found significant main effect of the instruction type on the time that participants took to complete tasks, $F(2, 40) = 6.26$, $p < .01$, partial $\eta 2 = .24$, indicating that specific instruction type results in different cost of time to complete task. In particular, Tukey's post-hoc test revealed that participants using allocentric instructions took least time (*M* = 214.59, *SD* = 110.78) and participants using landmark-based instructions took the most time (*M* = 319.41, *SD* = 117.36). Participants using egocentric instructions stayed in middle (*M* = 230.27, *SD* = 100.85). We also found significant between-subject effect of spatial abilities, $F(1, 20) = 12.12$, $p < .01$, partial $\eta 2 = .38$. In particular as shown in Figure 3, participants in the lower spatial ability group took significantly longer time (sec) to complete a navigation task (*M* = 296. 73, *SD* = 56.52) than participants in a higher spatial ability group (*M* = 212.79, *SD* = 56.52).

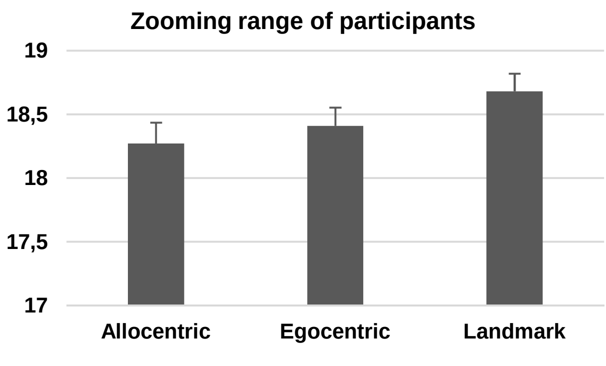
Figure 3: Time required to complete the map task in each instruction type.



We did not find significant effects of instruction type or spatial ability on the accuracy of performance in these tasks based on the total clicks and false clicks, p = .51. These results indicate that participants did not perform differently in our designed tasks.

After entering other measures as the dependent variable, we found significant difference among participants regarding their interactions with the web maps. In particular there is a significant main effect of instruction type on user's maximum zooming level on the online maps, $F(2, 40) = 4.82$, $p < .05$. As shown in Figure 4, Tukey's post-hoc tests revealed that participants in the allocentric instruction group zoomed the least (M = 18.27, SD = .79), those in the landmark-based group zoomed the most (M = 18.68, SD = .66), while those in the egocentric instruction group stayed in the middle (M = 18.41, SD = .67). We did not find that spatial ability had a significant effect on zooming interactions, p = .76.

Figure 4: Average maximum zoom level of participants in each instruction type.



4 Discussion and Conclusion

Although the sample size in this study is relatively small, some trends have already shown the impact of frames of reference on performance on web maps.

Different from suggestions in other studies, which focus on type of instructions on performance at environmental scale such as navigating in an environment, our study shows different findings. For example, landmarks are found more efficient in route instructions compared to instructions using street names and distances in navigation tasks in environments [20]. Here we found that participants using landmark-based instructions actually took longer time to learn and proceed the designed routes on web map. This is due to the change in frame of reference from an egocentric one to an allocentric one in task. As a map is the great resource to provide configurational knowledge using the allocentric frame of reference, it facilitates users to acquire the spatial configuration more efficiently than through landmarks. In contrast, when a person is in a physical environment, landmarks in environments are stored in an egocentric frame of reference. So when egocentric or landmark-based instructions are given, it does not require this person's change of frame of reference to perform navigational tasks.

Similarly, when navigating on web maps, which particularly have been aligned with north to the top, it is more efficient to follow instructions that contain information about cardinal directions, such as in the allocentric instruction condition. However, this does not always apply to navigating in a real environment.

When participants browse web maps, participants in the landmark-based instruction group have to zoom in to a greater level in order to locate those described objects accurately. This is also due to the fact that street networks are presented more predominantly on maps. Particularly at a small cartographic scale, no landmarks would be shown until participants zoomed in to larger cartographic scales.

Results from the current study support the challenge of presenting spatial information on maps for efficient wayfinding [21]. It is important to note that depending on the purpose of using maps, different types of spatial information should be designed and selected. When spatial tasks are performed at the same map space, the acquired spatial knowledge through allocentric instructions led to shorter duration, as there is no transition needed from an allocentric frame to another. But when those instructions are provided through egocentric and landmark-based frames, participants need to transfer their acquired frames of reference to an allocentric frame as represented in maps. Furthermore, if it is only for acquiring spatial configuration, maps are the most efficient way. But when the acquired spatial knowledge needs transferring to perform tasks like wayfinding in an actual environment, landmarks serve a more efficient role. There are also some issues in our study that need to be addressed as part of future work on this topic. For example, there is the imbalanced number of men and women in this study that we will address in our follow-up study. We aim to extend our analyses to a more comprehensive level that will help us identify those differences among instruction types and spatial abilities more thoroughly and inform efficient design of web maps for different wayfinding purposes.

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