Relationships between Methods for Presenting Information on Navigation Tools and Users' Wayfinding Behavior

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ABSTRACT

This study examines the effects of different methods for presenting navigational information on users' wayfinding behavior and spatial memory. In the first experiment, we examined tools that differed in the degree to which they induced the user to engage in deliberate route planning. We found that users of a tool that showed a route to the goal (the route tool*) had a poor scene-recognition memory and simply followed the directed route, compared to users of a paper map which did not show a route. A tool that showed the direction toward the goal (the* direction tool*) was equivalent to the route tool with respect to users' scene-recognition memory, but allowed users to take routes more varied than the route tool and as varied as the paper map did. The direction tool affected men and women differently, inducing the latter to make more turns. Our second experiment examined the effects of the size of the device screen, and found that the map's advantage of allowing the user to attend to their surroundings diminished when the map was shown in small size. We discuss implications for designing effective navigational aids in different situations.*

KEYWORDS: navigational aids; mobile systems; spatial behavior; spatial representations; location-based services

INTRODUCTION

Since antiquity, knowing about space and representing that knowledge in map form has been an essential part of human life, as indicated by the existence of ancient maps carved into stone or painted on cave walls (Black 2003). Maps are used for various purposes: for example, to depict the road network of an area, to show the spatial distribution of a specific variable of interest, or to delineate territorial boundaries. Importantly, maps show the locations of things and phenomena in the world schematically and at a reduced scale, and allow people to understand where they are in relation to other objects in the surroundings. Maps have thus been a major focus of research into human wayfinding and navigation (e.g., Blades et al. 1999, Liben et al. 2002, Lobben 2004).

Recently, with advances in information and communication technologies, many kinds of spatial representations and navigation tools other than traditional maps have been developed (Gartner et al. 2007, Meng et al. 2008). In 2004, the US Department of Labor identified geospatial technologies as one of the most important emerging and evolving fields (Gewin 2004). Use of various location-based applications is commonly observed now, including mobile maps, in-vehicle navigation systems, and dynamic traffic information services (Küpper 2005, Mannings 2008, Girardin and Blat 2010).

These novel navigation tools have attracted the interest of researchers concerned with their effect on the user's wayfinding and spatial learning. Axon et al. (2012) argued that satellite navigation systems were perceived differently from traditional maps and could potentially change people's wayfinding behavior. Frean (2006) reported a concern that the use of satellite navigation systems might have negative impacts on people's geospatial literacy and awareness. Notably, findings from past research suggest that such technologically advanced systems do not necessarily serve the expected purposes of assisting the user in navigation and environmental learning.

In the literature of spatial cognition, a distinction has been made between *navigation* and *wayfinding*. Montello (2005) defined navigation as consisting of locomotion and wayfinding, the latter of which involves goal-directed and planned movement of one's body in an environment. Taylor et al. (2008) discussed navigation as a special case of wayfinding where simple motor sequences or supportive mechanisms are used. Thus navigation involves less decision making or cognitive processing than wayfinding, in that a person follows a prescribed series of directions without the necessity of relying on internal representations of an environment. The present study aims to examine how navigation tools differing in the degree to which they induce or require the user to engage in route planning (i.e., wayfinding, as opposed to locomotion or navigation, in the above definitions) affect the user's spatial behavior and environmental learning. And the degree is varied in this study by the format of presenting navigational information on the tools.

In the literature, spatial knowledge has often been discussed in terms of landmark, route, and survey knowledge (Siegel and White 1975), and individual and group differences in the acquisition and use of these types of knowledge have been reported. Some people quickly acquire accurate survey knowledge in a new environment, whereas others stay at the levels of landmark and route knowledge even with repeated exposure to the environment (Ishikawa and Montello 2006). Similarly, people differ in the strategies of wayfinding, some using landmark- or route-based strategies and others using survey-type strategies (Pazzaglia and De Beni 2001). Men tend to perform better than women on spatial tasks that require survey (or configurational) understanding of environments (Ishikawa and Montello 2006), and in giving navigational directions men tend to use cardinal directions, while women use landmarks and egocentric (left-right) reference frames (e.g., Dabbs et al. 1998, Montello et al. 1999).

Accordingly, the use of navigation tools has been studied with respect to their effects on the acquisition of the three types of knowledge. Past research showed that users of navigation tools had difficulty acquiring accurate survey knowledge, compared to people who used maps or directly experienced routes (e.g., Krüger et al. 2004, Aslan et al. 2006, Münzer et al. 2006, Ishikawa et al. 2008, Willis et al. 2009).

In the present study, however, another type of spatial knowledge than landmark-route-survey knowledge is examined: people's memory of scenes in traveled environments. The reason is that having a good memory of the surroundings constitutes an important part of an enjoyable travel experience, as contrasted with heading to a destination without any attention to the surroundings. Concerning the characteristics of spatial behavior and learning by mobile users, Münzer et al. (2006) showed that users of mobile navigation tools did not remember the locations and directions of intersections as well as users of maps. Ishikawa et al. (2008) showed that mobile users traveled longer distances and stopped more frequently during travel than map users did.

As possible reasons for the ineffectiveness of navigation tools, two explanations have been suggested. The first concerns whether the user engages in conscious decision making about which route to take (i.e., deliberate route planning vs. simple following of route directions). Researchers described users of navigation tools as simply following the provided route instructions, and ascribed their degraded spatial learning to the lack of route planning or decision making (Péruch et al. 1995, Gaunet et al. 2001, Parush et al. 2007, Bakdash et al. 2008). In particular, Farrell et al. (2003) and Burnett and Lee (2005) discussed how the control of decisions about which route to take is an important component of deliberate route planning.

A second explanation concerns the size of the device screen. On mobile tools, maps are shown at a small size, and route information is provided in a piecemeal fashion without the whole route being visible simultaneously. This fact has been found to affect the user's wayfinding performance and knowledge about traveled routes (Dillemuth 2009, Willis et al. 2009, Gartner and Hiller 2010).

The present study addresses these two explanations by examining the effects that different methods for presenting navigational information have on the user's wayfinding and spatial learning. Specifically, it looks at people's travel behavior and memory of surrounding scenes when they use different navigation tools (we note that in this study, these tools are used "in situ" rather than for pre-planning purposes). Although past research suggests that the ineffectiveness of navigation tools relates to the users' simple following of directed routes, it still remains to be empirically examined to what extent the users merely "follow" the directions. Therefore, this research examines the variation in the routes that users of different navigation tools take, by allowing them to choose their own routes to reach a goal. It also examines their memory of the surrounding scenes and the length of time that they look at the tool, as measures of the degree of attention paid to the tool versus to the surrounding space. The rationale is that in tourist navigation, helping the user to remember visited places is desirable, since simply moving between the start and goal without any memory of the places in-between may not be too enjoyable for the tourist.

To that end, two experiments were conducted. The first experiment focused on the issue of deliberate route planning versus simple direction-following, by comparing navigation tools that show a route to the goal or the direction toward the goal with a paper map. If a tool that shows which route to take renders the task of navigation mere direction-following, users would take similar and less varied routes and remember the surrounding scenes poorly.

The second experiment focused on the size of the device screen, by allowing users to view a map for the whole route on the screen. If a map presented in smaller size distracts the users' attention from the surrounding space to the tool, their wayfinding performance and memory for the surroundings would be poor. Both experiments took into consideration sex-related differences in wayfinding as well, looking at whether the different navigation tools affect wayfinding behavior by men and women differently.

EXPERIMENT 1

METHOD & MATERIALS

Participants. Twenty-four college students (12 men and 12 women) participated in the experiment, ranging in age from 19 to 24 years with a mean of 22.3. They were students in various disciplines, including urban planning, environmental studies, geography, and computer science. Their experience in the use of maps and navigation tools was not found to correlate with the wayfinding behavior and spatial memory examined below.

Study Area. As the study area, a commercial district in Aoyama, Tokyo, was used. It is a popular area for street shopping and allows us to observe people's wayfinding behavior while they are walking around with interest in the surrounds. In the area, we selected three pairs of start and goal locations (i.e., participants traveled three routes), which were 770, 760, and 1,060 m apart, respectively, along the shortest route (Figure 1).

Navigation Tools. We developed two methods for presenting navigational information on a GPS-based smartphone system: a *route tool* and a *direction tool*. Both tools received good GPS signals in the study area and presented navigational information with good accuracy.

The route tool presented the shortest route to the goal. On the device screen (8.9 cm [3.5 in] in diagonal), a map of the area within a 150 m radius was shown in a north-up

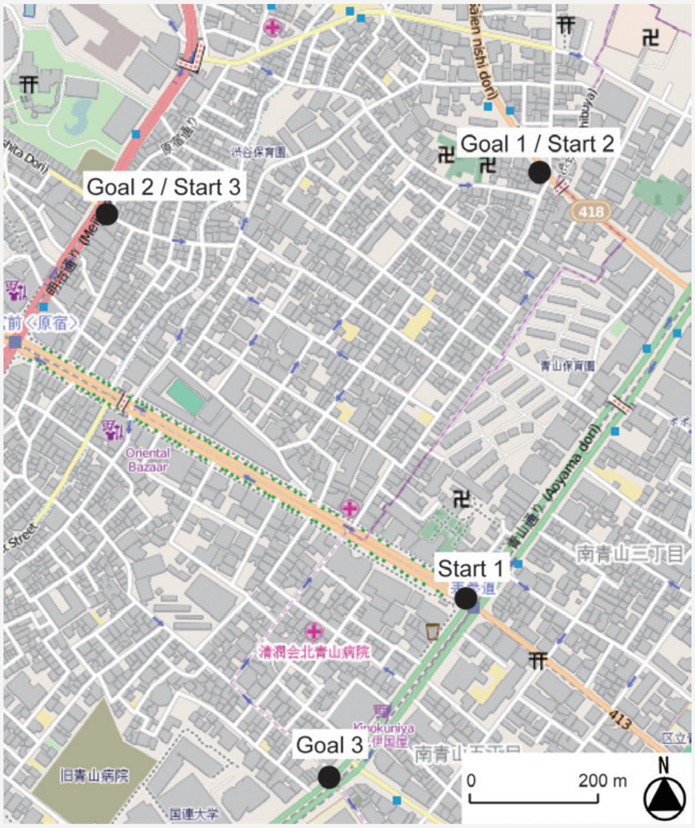

Figure 1: Map of the study area. Three pairs of start and goal locations were selected in the area. Participants walked between the locations in each pair using one of three navigation tools in counterbalanced order. © OpenStreetMap contributors. http://www.openstreetmap.org.

orientation, and the user's current location was updated according to their movements in space (Figure 2A). Due to the limited size of the screen, the start and goal locations were not shown simultaneously on the screen, and only part of the whole route was presented.

The direction tool presented the direction in which the goal was located relative to the user's current location (Figure 2B). No specific routes were indicated. A map of the area within a 150 m radius and the user's current location were updated according to their movements. The start and goal locations were not shown simultaneously on the screen. The direction tool was intended as a presentation format lying between the route tool and the paper map, in the sense that it does not show which route to take as the route tool does, and presents information on a small screen in a more relational (or survey-type) manner like maps.

Figure 2: Information provided by navigation tools. (A) On the route tool, the user's current location (the symbol around the center of the screen) and a route to the goal (the solid line from the start, denoted by an A, toward the lower-left corner of the screen) were shown. (B) On the direction tool, the user's current location and the direction toward the goal (the blue arrow pointing to the lower-left corner of the screen) were shown. (C) A map for the whole area that was available upon request to users of the route tool in Experiment 2. (D) The device-screen map used in Experiment 2, with the stat and goal denoted by A and B. (Tools developed with Google Maps API. Map data © 2011 Google, ZENRIN.)

Paper Maps. A third method for presenting navigational information was a map printed on A4-sized paper with a scale of about 1:6,000 (chosen to match to maps in major travel guidebooks). On the paper map, the start and goal locations were marked, without any specific routes to the goal being indicated.

Of the three tools, the route tool provides specific instructions about which path to take, while the direction tool and the paper map provide information that is not tied to one route. The former shows the direction toward the goal on a screen of limited size and the latter shows the spatial relations between the start and goal locations.

Scene Recognition Task. After walking the three routes, participants viewed photographs and answered whether they had seen the scenes along the routes, on a 4-point scale (1 = *I certainly did not see it*; 2 = *I probably did not see it*; 3 = *I probably saw it*; 4 = *I certainly saw it*). Some of the photographs were scenes visible from the routes that participants took, and others were not.

For this task, 110 photographs were prepared in advance, which were taken along a wide variety of routes that we thought participants would possibly take. Thus we were able to select the photographs presented as visible and nonvisible scenes according to the routes that they had taken. The average number of photographs presented to participants was seven for visible scenes and eleven for nonvisible scenes.

Measured variables. Concerning participants' wayfinding behavior, we measured (a) travel distance (standardized by the distance for the shortest-path route), (b) travel speed (given by the travel distance divided by travel time), (c) memory of the surrounding scenes, (d) the time that they spent looking at the tools, and (e) the degree of similarity between the routes that participants took.

Design and Procedure. Participants walked between the three pairs of start and goal locations using one of the three tools: the route tool, the direction tool, or the paper map. In the experiment a repeated measures design was employed, and the allocation of the three tools to the three pairs of start and goal locations was counterbalanced across participants.

At the beginning of the experiment, participants were taken individually to the first start location and given one of the three tools. They were instructed that their objective was to go toward the goal, not to follow the specific routes that some of the tools would present, and that they were allowed to choose their own routes as long as they reach the goal. These instructions were intended to induce participants to not necessarily follow the route directions and to enable us to examine the variability of participants' routes with different tools.

The experimenter explained the information that each tool would present, and ensured that participants learned how to use it. We ensured that participants understood their current location and orientation at the start by having them align the tool with the surrounding space (with assistance if necessary). When they indicated that they were ready, participants started to walk toward the first goal. During the walk, they raised no questions or complaints about the operation of the tool. When participants reached the first goal, they were told that they would engage in the second travel from there, and started to go toward the second goal using another tool.

At the end of the experiment, participants answered a questionnaire which asked about their age, degree of interest in the study area, familiarity with the traveled routes, and experience in using navigation systems and maps. It took 90 min on average to complete all tasks.

Participants also filled out the Santa Barbara Sense-of-Direction scale, which consists of fifteen 7-point Likert-type questions about navigational abilities or preferences (Hegarty et al. 2002). People having higher scores on this scale have been shown to do better on updating their orientation and location in space as a result of self-motion. We thus used this scale as a possible correlate with participants' wayfinding behavior, but observed no significant effects (in both Experiments 1 and 2). This lack may have stemmed from the fact that sense of direction is more related to the understanding of configurational properties of the environment (i.e., survey knowledge) than to route following (Hegarty et al. 2006).

RESULTS

Travel Distance and Speed. Since the routes were not complex, all participants succeeded in reaching the goals. For each participant, we computed the distance traveled and the mean travel speed, and examined the differences among the three tools in a mixed analysis of variance (ANOVA), with the tool used (route tool, direction tool, or paper map) as a within-subject variable and sex (male or female) as a between-subject variable. An alpha level of 0.05 was used for all statistical tests.

There were no significant main or interaction effects for the distance traveled. There was a significant main effect of sex for the mean travel speed, $F(1, 22) = 9.29, p < 0.01$, with men traveling faster than women (Figure 3A, open symbols).

Scene Recognition. For each participant, we computed a memory-performance score, weighted by their degree of confidence. The score was given as the sum of the number of correctly identified scenes with greater confidence (i.e., *I certainly saw* [or *did not see*] *it*) multiplied by 2 and the number of correctly identified scenes with less confidence (i.e., *I probably saw* [or *did not see*] *it*), divided by the total number of scenes.

There was a significant main effect of the tool used, $F(2, 21) = 5.29, p < 0.05$. Post hoc paired comparisons (Bonferroni)

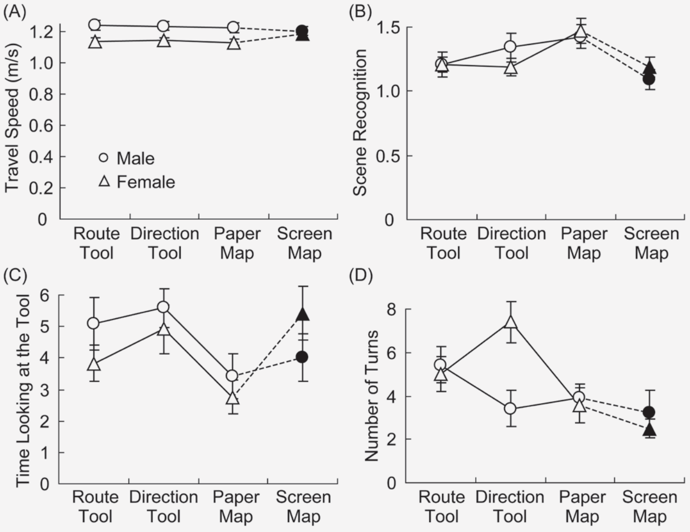

Figure 3: Comparisons of wayfinding measures for different tools: (A) travel speed, (B) scene recognition (memory-performance scores), (C) time spent looking at the tool (relative to travel time, out of 10), and (D) the number of turns that users made. Open symbols are for the three tools in Experiment 1, and solid symbols are for the device-screen map in Experiment 2. Vertical lines depict standard errors of the means.

showed that participants remembered the surrounding scenes better when using the paper map than when using the route tool (Figure 3B, open symbols).

Time Spent Looking at the Tools. In the questionnaire, participants indicated the length of time that they spent looking at each tool relative to their travel time, from 0 (*not at all*) to 10 (*all the time*). We confirmed that these responses were consistent with the experimenter's observations.

There was a significant main effect of the tool used, $F(2, 21) = 7.63$, $p < 0.01$. Post hoc comparisons showed that participants looked at the direction tool for a longer time than the paper map (Figure 3C, open symbols).

Similarity between Participants' Routes. To examine the degree of similarity between the routes that participants took, we computed cosine similarity between pairs of participants' routes. This measure is often used in text mining to compare the similarity between two documents represented as vectors (Tan et al. 2005). In our case, the similarity value, ranging from 0 to 1, is given by the equation

$$S_{ij} = L_{ij} / \sqrt{L_i L_j}$$

where

S_{ij} = similarity between participant *i*'s and participant *j*'s routes,

L_{ij} = length of route segments shared by the two participants' routes,

L_i = length of participant *i*'s route, and

L_j = length of participant *j*'s route.

In paired comparisons (Bonferroni), participants' routes were more similar to each other when using the route tool than when using the direction tool and the paper map, the latter two of which did not differ significantly (Figure 4, open circles). That is, participants tended to follow the routes as directed by the route tool, and to take a wider variety of routes when using the direction tool and the paper map (see the maps in Figures 5A–5C).

To examine the characteristics of the routes that users of the three tools took, we looked at the number of turns that participants made. An ANOVA and post hoc comparisons showed that men made fewer turns than women when using the direction tool (Figure 3D, open symbols), $F(2, 21) = 4.69$, $p < 0.05$.

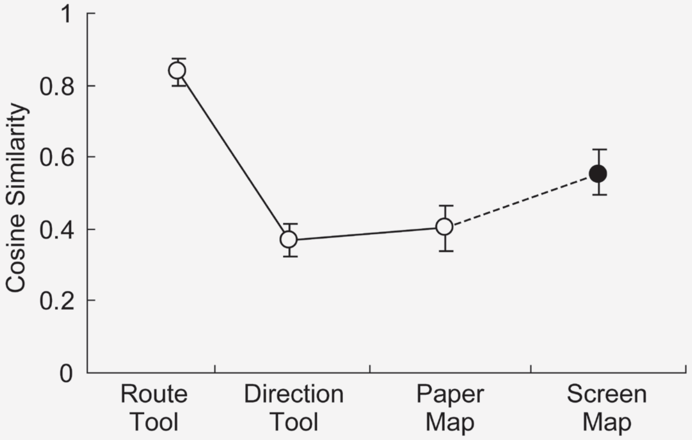

Figure 4: Cosine similarity values for different tools. Open circles are for the three tools in Experiment 1, and a solid circle is for the device-screen map in Experiment 2. Vertical lines depict standard errors of the means.

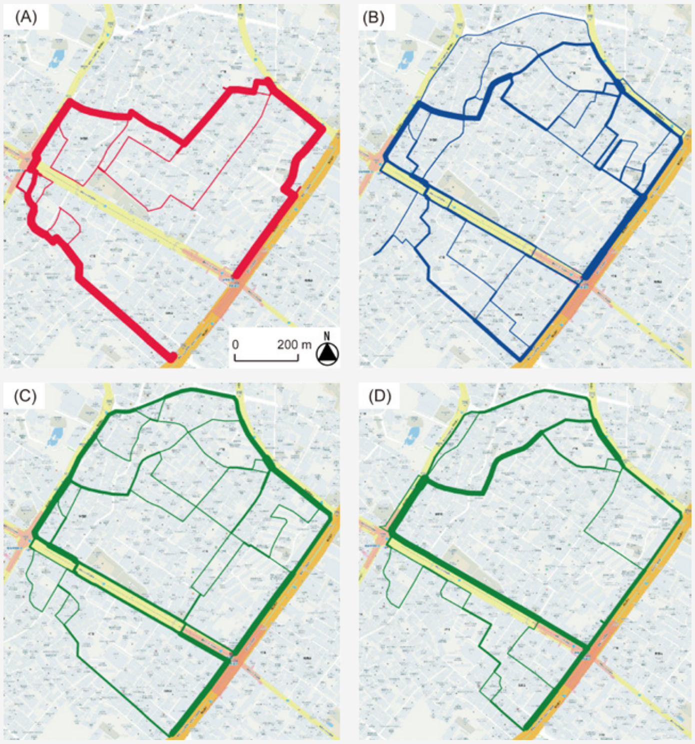

Figure 5: Maps showing the routes that participants took when using (A) the route tool, (B) the direction tool, (C) the paper map (in Experiment 1), and (D) the device-screen map (in Experiment 2). The thickness of the lines is proportional to the number of participants who traveled each route.

Relationships with Interest, Familiarity, and Experience. In the questionnaire, participants were asked about their degree of interest in the study area, familiarity with the traveled routes, and experience in using navigation systems and maps. To measure their degree of interest, participants indicated on a 5-point scale how much they were interested in the study area in terms of doing shopping, enjoying the townscape, seeing famous buildings or places, discovering new things, and learning about the area (a mean score of their responses to these questions was computed). For familiarity, participants answered how many times they had been to the study area. To determine their experience with navigation tools and maps, participants were asked how often they used them on a 5-point scale: 1 (*never used before*), 2 (*less than once a month*), 3 (*a few times a month*), 4 (*a few times a week*), 5 (*use every day*). Correlations of these variables with the observed measures of participants' wayfinding behavior were examined.

When using the paper map, participants who were more familiar with the study routes tended to travel more slowly and remembered the surrounding scenes better ($r = -0.41$ and 0.48, respectively, $p < 0.05$). Those who were more interested in the study area also traveled more slowly ($r = -0.43$, $p < 0.05$). When using the direction tool, participants who had greater experience in using navigation systems were worse at remembering the surrounding scenes, $r = -0.47$, $p < 0.05$.

In the questionnaire, participants also commented on the use of the three tools. For the route tool and the direction tool, their comments indicated that they wanted to view the entire route and know where the goal was located. For the direction tool, some participants mentioned that they preferred to know about routes, rather than the direction in which the goal was located. For the paper map, they wanted their current location and a specific route to be indicated, because they had difficulty knowing where they were located.

EXPERIMENT 2

In the first experiment, paper map users remembered the surrounding scenes better and looked at the map for a shorter time, indicating that it has the advantage of allowing users to attend to the surroundings without distracting them. There seem to be two possible reasons for this advantage: (a) because the paper map showed the whole route between the start and goal or (b) because the paper map showed information in a larger size (on A4-sized paper vs. the 3.5-inch device screen).

To examine these two possibilities, we conducted an experiment in which a map for the whole route was shown on the device screen. In the second experiment, the route tool and the direction tool were provided with an option of allowing the user to view a map for the whole route on the screen, and the paper map was replaced by a smaller, on-screen map with a smaller cartographic scale.

If possibility (a) above is correct, participants in the second experiment would do as well as the users of the paper map in the first experiment. If possibility (b) is correct, participants would perform similarly to the users of the route and direction tools in the first experiment.

METHOD & MATERIALS

Participants. Twenty-four college students (12 men and 12 women) participated in the experiment, ranging in age from 18 to 33 years with a mean of 21.8. These participants did not know about the first experiment. Similar to Experiment 1, they were students in various disciplines and their experience in the use of maps and navigation tools did not relate to the wayfinding behavior and spatial memory examined below.

Study Area. The same study area and the same three pairs of start and goal locations were used as in Experiment 1.

Navigation Tools. By modifying the navigation tools used in Experiment 1, we developed three methods for presenting navigational information on a GPS-based smartphone system. Two of the methods were the same as the route and direction tools used in Experiment 1, except that in Experiment 2 the user was allowed to (a) view a map of the whole area between the start and goal locations on the screen for 7 seconds by pressing a button (Figure 2C) and (b) change the map scale (to zoom in and zoom out). On average, participants viewed a map for the whole area 1.8 times, and changed map scale 0.6 times, with no significant differences between the route and direction tools.

A third method was a static map shown on the device screen, which we will call a *device-screen map*. As the paper map in Experiment 1, it shows a map for the whole route (or area) between the start and goal, with the start and goal locations being marked (Figure 2D).

Measured Variables. We measured the same variables as in the first experiment concerning participants' wayfinding behavior.

Design and Procedure. Participants walked between the three pairs of start and goal locations using one of the three tools: the route tool, the direction tool, or the device-screen map. As in Experiment 1, a repeated measures design was employed, and the allocation of the three tools to the three pairs of start and goal locations was counterbalanced across participants. The experimental procedure was the same as that for Experiment 1. It took 90 min on average to complete all tasks.

RESULTS

Travel Distance and Speed, Scene Recognition, and Time Spent Looking at the Tools. As in Experiment 1, all participants succeeded in reaching the goals. For the measured variables of travel distance and speed, scene recognition, and the time spent looking at the tools, there were no significant differences among the three tools in Experiment 2 (which is reasonable as the users of all three tools viewed a map for the whole route on the screen).

Therefore in the section below, we compare the performance for the device-screen map (solid symbols in Figure 3) to that for each of the three tools in Experiment 1 (open symbols in Figure 3), with a view to examining the two hypotheses ((a) and (b) mentioned above) in detail. Specifically, we employed an ANOVA with the tool used and sex as between-subject variables.

Relationships with Interest, Familiarity, and Experience. When using the device-screen map, participants who were more familiar with the study routes tended to look at the tool for a shorter time, $r = -0.47$, $p < 0.05$.

As in Experiment 1, participants commented on the use of the three tools in the questionnaire. For the route tool and the direction tool, their comments indicated the desire to know the location of the goal, and thus to have the map for the entire route available all the time. For the device-screen map, many participants complained about the small size of the map and consequently the coarseness of the depicted information. A few participants wanted the map shown on the tool to be rotated automatically in alignment with their heading directions in the environment.

COMPARISON OF THE DEVICE-SCREEN MAP IN EXPERIMENT 2 WITH THE THREE TOOLS IN EXPERIMENT 1

Travel Distance and Speed. For travel distance, there were no significant main or interaction effects. For travel speed, there was a significant main effect of sex, indicating that men traveled faster than women: Fs(1, 44) = 4.97, 4.91, and 4.53, for the comparisons of the device-screen map with the route tool, the direction tool, and the paper map, respectively, $p < 0.05$ (Figure 3A). These results show that participants' travel distance and speed did not differ depending on the tools, and men traveled faster than women with all tools.

Scene Recognition. In the scene recognition task, performance with the device-screen map was worse than with the paper map, $F(1, 44) = 11.96$, $p < 0.01$, but was not significantly different from the route and direction tools (Figure 3B). These results show that when the map was shown in small size on the device screen, the (paper) map's advantage of fostering the user's scene recognition memory diminished, down to a level equivalent to the route and direction tools.

Time Spent Looking at the Tools. The time spent looking at the tools was longer for the device-screen map than the paper map—$F(1, 44) = 4.98$, $p < 0.05$—but was not significantly different from the route and direction tools (Figure 3C). As with scene recognition, these results show that when the map was shown in small size on the device screen, the map's advantage of allowing the user to attend to the surroundings diminished, with their attention being on the tool.

Similarity between Participants' Routes. As in Experiment 1, we examined the degree of similarity between participants' routes through a cosine similarity measure. Paired comparisons showed that the similarity value for participants' routes was larger for the route tool than for the device-screen map, which in turn had a larger similarity value than the direction tool and the paper map (Figure 4 solid circle, and Figure 5D).

We also examined the number of turns that participants made. The number of turns for the device-screen map was smaller than the route and direction tools: *F*s(1, 44) = 8.60 and 9.19, respectively, $p < 0.01$. It was not significantly different than the paper map. There was a significant interaction of the tool used and sex for the comparison of the device-screen map with the direction tool, indicating that women made more turns than men when using the direction tool: $F(1, 44) = 8.03$, $p < 0.01$ (Figure 3D).

DISCUSSION

Results from the first experiment show that when using the route tool, people remember surrounding scenes poorly, spend a longer time looking at the tool, and tend to follow the provided routes as directed by the tool. Compared to paper maps, their scene recognition memory was 20% lower, the length of time that they looked at the tool was 30% longer, and their routes were half as varied. That is, while paper map users attend more to the surrounding space than to the tool, route tool users simply follow the route instructions while paying less attention to the surroundings. Although it is popular for major commercial navigation systems to direct the user as to which route to take, this seems to have the negative effect of rendering the act of navigation into simple direction-following. The results also indicate that people do not always take the shortest-path route, as the route tool in this study instructed the user to do.

The direction tool was intended to lie in between the route tool and the paper map, in the sense that its instructions were not tied to a specific route, but presented in a more relational manner. The results showed that the direction tool was equivalent to the route tool with respect to the user's scene recognition memory and the time that they spent looking at the tool. The direction tool also allowed the user to take more varied routes than the route tool and as varied routes as the paper map did.

The direction tool also affected men and women differently, inducing the women to make more turns than men. This may be explained by the tendency of women to rely on landmarks and egocentric information in navigation: women turned as frequently as the direction shown by the tool changed, owing to subtle changes in their heading directions. By contrast, since men tend to consider the configurational or allocentric properties of the environment, they were not disturbed by subtle changes in heading and moved in the general direction in which the goal was located. Men approached the wayfinding task from a global perspective, women from a more local perspective. Interestingly, participants who had more experience using commercial navigation systems were worse at remembering the surrounding scenes when using the direction tool. This implies that becoming used to following route directions makes globally oriented navigation difficult.

Participants' comments about the route and direction tools are also suggestive about route planning and configurational learning with these tools. Many participants mentioned that they wanted to view the entire route and to know where the goal was located. It indicates that these tools require the user to follow directions without knowing where they are heading or having a mental picture of the whole route. At the same time, participants' comments show that some people find it difficult to understand where they are located when using maps.

A practical implication of the results is that the direction tool may work in a situation where the "navigator," or the provider of navigational information, aims to expose the user to various places along various routes: for example in tourist navigation or sightseeing. In contrast, for a situation in which the navigator's principal objective is simply to guide the user to the goal, the route tool may be appropriate. But when the navigator wants the user to leave the visited places with a good recollection of the surroundings and the experience of traveling various routes, paper maps may be a good choice, at least for routes and environments that are not too complex.

In the second experiment, participants who viewed the map on the device screen in small size remembered the surroundings poorly, looked at the tools for a longer time, and took less varied routes, when compared to those who used the paper map in the first experiment. Thus the map's advantage of allowing the user to attend to their surroundings diminishes when it is shown in the small size of a device screen. As with the learning of configurational properties of environments (Dillemuth 2009, Willis et al. 2009), the learning of surrounding scenes or scene recognition memory is affected by the size of the device screen.

SUMMARY

Our results show that the presentation format commonly used on current navigation systems does not help the user to remember their surroundings or provide them with the enjoyment or freedom of exploring divergent routes as well as a paper map does. Also, a map's strength of allowing the user to comprehend the layout and spatial relations of objects is weakened when it is shown on a small smartphone screen.

Thus the format for presenting navigational information does affect users' wayfinding behavior and spatial memory. To better understand the use of advanced navigation tools, more research from the perspective of human cognition and behavior, as well as from a technological perspective, is needed. Possible areas for further research include the level of generalization and map symbolization appropriate for mobile systems and users' preferences or strategies in wayfinding and navigation. The effects noted in this study of a user's prior experience with navigation systems also deserve further investigation. Continued empirical research on these issues would lead to the development of effective navigational aids that can adapt to various user attributes and wayfinding situations.

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