Influence of Map Design, Individual Differences, and Environmental Cues on Wayfinding Performance

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This exploratory study investigated the effects of map design, individual differences, and environmental cues on wayfinding performance in an outdoor recreational area. Six maps, with three contour representations and two color codes, were used to determine how map design influences wayfinding. Four individual differences: gender, experience in map usage (experience vs. novice), handedness, and cultural difference (local vs. international), were used to predict wayfinding performance. The study area consisted of a trail park with ten junctions, where three of the junctions had signs, as environmental cues to aid users. Multiple regression analyses and logistic regression analysis were performed to predict the total time of completion, time for decision-making, accuracy of decision-making, and total time deviated from route. Results showed that only cultural difference and signage significantly predicted decision-making accuracy, and cultural difference was a significant predictor of total time deviated from route. Design implications for use of cues and wayfinding are discussed. In addition, recommendations for maps, trail networks, and environmental design are provided.

Keywords: Map design, individual differences, environmental cues, outdoor recreational area, wayfinding.
Introduction

Navigation using a paper map in an outdoor area is a complex cognitive task that requires the user to interpret and understand the map, and to relate information from the map to the environment (Blades & Spencer, 1987). There are millions of recreational visitors to the various National Parks and outdoor recreational areas in the United States alone. For example, in year 2000, there were 286 million visitors to all National Parks in United States (National Park Service, 2000). The National Park Service has conducted approximately 150,000 search and rescue missions in national parks (Farabee, 1998) with results of lost persons ranging from mild hypothermia to death. Yet, there are few studies examining the effects of map designs, individual differences, and environmental design on wayfinding performance in real-world, potentially hazardous settings. Yarnal and Coulson (1982) compared three map designs for the Lake O’Hara region in Yoho National Park, British Columbia, Canada. In another outdoor recreational area, Clarke (1989) studied user feedback of a monochrome schematic map of trails in the park. Both studies however, focused on users’ feedback on map design, such as color-coding and map details, rather than actual wayfinding performance based on map features.

Numerous laboratory-based studies were conducted to investigate map knowledge acquisition processes (Evans & Pezdek, 1980; McNamara, Ratcliff & McKoon, 1984; Sholl, 1987; Thorndyke & Stasz, 1980; Warren, 1994), but the impacts on map design based on such studies were seldom consolidated or validated. Such studies, however, provide insights to the processes used by map users when reading maps and encoding map information into the so-called cognitive map (Golledge, 1999). Cartographers traditionally tried to integrate cognitive map research, information processing theory and communication theory into the art of map making (Board, 1978; Keates, 1982; Kolancy, 1969; MacEachren, 1995; Medyckyj-Scott & Board, 1991; Robinson & Petchenik, 1976; Wood, 1972). Medyckyj-Scott & Board (1991) however argued that cognitive approaches to map use have little relevance for map design. They recommended more realistic map testing on map users as well as on map designers, and advocated the development of a design approach similar to engineering where the design specification is given before the map is produced.

Further efforts of Blades and Spencer (1987) provided reviews of literature of navigational map usage in diverse fields. They found that, in general, people had difficulty reading and using maps, and would avoid using maps totally in unfamiliar environments. They concluded that either map usage is an inherently difficult cognitive skill or maps are not designed to suit the user. They recommended that more direct testing of “different map designs in the environment” should be conducted “to find out how map design can affect individuals’ use of maps” (Blades & Spencer, 1987, p.73).

Given the existing gaps in knowledge of user-centered map design, this study used a real-world wayfinding task to elucidate the impact of map designs on actual performance in line with the aforementioned recommendations by Blades
and Spencer (1987). Map features, such as contour representations and color representations, were varied to investigate differences in performance. Individual differences of users and environmental cues in terms of signage presence were also used to predict wayfinding performance. Justifications for the selection of these features are provided in the subsequent sections.

**Color-coding of Maps**

Color maps for outdoor areas have the benefit of supporting better discrimination between map features due to redundancy in coding of symbols (Keates, 1982). Head (1972) compared various monochrome representations of land-water features and found that several cartographer conventions of land-water representation were not obvious to the untrained user. His study did not account for in-land water features such as rivers and streams that can be confused with roads, tracks, trails or contour lines. Representation of water features in black-and-white maps can be potentially difficult to discriminate from the other map features. In a similar exploration, Yarnal and Coulson (1982) used three different maps for their survey of users’ preferences: Continuous Monochrome maps, Continuous Color maps, and Trail specific maps. Users preferred color maps compared to monochrome maps. Similar recommendations were given in Clarke’s study (1989), where a high percentage of users asked for color in maps. Devlin and Bernstein (1997) investigated effects of color, level of detail, label placement of a tourist map for a pier area, taking into account gender, and handedness of users using an interactive wayfinding task in a computer kiosk. In contrast to other studies, Delvin and Bernstein’s (1997) findings on color-coding showed that color maps might not be essential to wayfinding as color did not improve or decrease performance. A similar finding was obtained by Garland, Haynes, and Grubb (1979), using bus transit maps, where monochrome maps with fewer details led to similar performance relative to colored maps. These apparent contradictions in the usefulness of color may reflect dissociation between preference of users and actual performance. However, the map usage contexts also differed and color might be important in an outdoor map due to difficulty in representing terrain features, such as water features, and contour lines.

**Level of Detail**

For outdoor maps, the level of detail, such as the types of elevation representation, and amount of information on the map, can affect legibility depending on the size and scale of the map area (Keates, 1982). For a map with a small scale, lower level of detail (less contours, and less information) would be preferred to reduce clutter. On the other hand, the amount of actual information available in the map would be reduced with a lower level of map detail. Outdoor maps are usually represented with contour lines as in topographic maps. The contour lines give three dimensional terrain information so that a trained person can use it for navigation (Mooers, 1972) as well as for identify
geographical features such as creeks, ridgelines, and valleys (Bies & Long, 1983). However, not everyone knows how to read contour lines effectively. Tkacz (1998) reported a study by Cross, Rugge and Thorndyke (1982) that found that neither acknowledged expert nor non-expert United States Marines were able to visualize the real world appearance of landforms portrayed with contour lines. This showed that attempts to match the landforms of the actual ground to the contour lines information might be difficult and users might not necessarily benefit from the contour lines in terms of wayfinding.

Other alternatives to contour lines are shaded relief and no contour lines. In shaded relief maps, elevations are presented as if the hills cast a shadow due to light in the northwestern direction (Anson & Ormeling, 1993; MacEarchren, 1995). This technique produces a three dimensional impression of the relief with less cluttering effects compared to contour lines. The shaded relief map might be more intuitive to the user and is expected to better support terrain interpretation by novice map users. However, the contour information in a shaded relief map is less precise compared to a topographic map (contour map), which if learned, can be used to calculate the exact gradient of a slope. A schematic map with no contour information is arguably the least cluttered map design compared to contour lines and shaded relief, but does not have any information on the landform of the actual ground. Delvin and Bernstein (1997) found no significant performance differences in level of map detail.

**Gender Differences**

Delvin and Bernstein’s (1997) results on gender differences were consistent with earlier studies by Galea and Kimura (1993), where females were found to take longer to complete wayfinding tasks and were less accurate in terms of wayfinding performance compared to males. Pedersen (1999) administered a self-rating Environmental Competence Scale and found that males rated themselves more competent in outdoor skills and wayfinding abilities than females, which indicates that there is a difference in confidence level between males and females. Delvin and Bernstein’s earlier work also found that males made significantly fewer errors compared to females when doing computer-simulated wayfinding (Delvin & Bernstein, 1995).

In a large-scale real-world wayfinding study of 978 military college students (132 were women), Malinowski and Gillespie (2001) measured the wayfinding performance of the participants to investigate differences due to gender, self-reported map skills, previous activities, math scores, and anxiety/emotional disposition. Results showed that gender, self-reported map skills, mathematical abilities, and previous activities were significant predictors of performance in a multiple regression analysis. The female participants were found to perform worse than the male participants. Other related studies showed that there were gender differences in wayfinding strategies and accuracy, indicating better performance by males (Lawton, 1996; McGuiness & Sparks, 1983; Miller & Santoni, 1986; Ward, Newcombe, & Overton, 1986).
User Experience

Experience in map usage and wayfinding activities could affect wayfinding performance. Saku (1992) showed that geography students performed better than psychology students in contour map reading and route planning tasks. Students in each department were further divided into two groups, where one group received 20 minutes of training in geographical lexemes. The training groups from each department performed better than the non-training groups. Tkacz (1998) also showed that not only map reading can be taught, but navigational techniques can also be taught to enhance navigation skills. Tkacz (1998) administered orientation instructions through a Map Interpretation and Terrain Appreciation Course (MITAC) to untrained soldiers and compared their performance in terrain association and location positioning with three control groups. The results showed that the group exposed to MITAC performed better. The performance enhancement was also shown to be independent of spatial abilities. Crampton (1992) used “think aloud” protocols to elicit mental models of experts and novices in planning routes using a topographic map. Experts and novices were shown to exhibit different strategies in wayfinding under laboratory conditions. Crampton suggested that experts gained survey knowledge while novices gained route-based knowledge when reading the maps. Previous experience was also found to increase performance in a real-world wayfinding task (Malinowski & Gillespie, 2001).

Handedness of Users

Handedness may also be a factor that influences wayfinding performance. The right hemisphere dominance of some left-handers has been shown to make significantly fewer errors than right-handers in the computer kiosk wayfinding task in Delvin and Berstein’s study (1997). Right hemisphere dominance of left-handers has been reported to be associated with higher creativity and better mental rotation skills ((Burke, Chrisler, & Delvin, 1989; Coren, 1993; Newland, 1981; Porac & Coren, 1981; Stewart & Clayson, 1980). Mental rotation was believed to be important to wayfinding when comparing map orientation with terrain (Aretz, 1991; Aretz & Wickens; 1992; Goldberg, MacEachren, & Korval, 1992; Gugerty, deBoom, Jenkins, & Morley, 2000). Better skills in mental rotation may not be important if users are allowed to rotate their maps in the direction of movement instead of mentally rotating the map to match the terrain. Handedness of users was accounted for in this study to investigate whether handedness predicted wayfinding performance in an outdoor wayfinding task.

Cultural Differences

In general, it has been observed that National Parks have high annual percentages of international visitors, although there are no reliable statistics to support this assertion. There are, however, few studies that examine cultural differences in usage of outdoor recreational areas. International visitors might not be familiar with map design conventions used by map designers in terms of
map symbols and trail labels. Gerber, Burden, and Stanton (1990) proposed a systematic approach to design public information symbols to cater to tourists. They proposed standardizing symbols used in tourist and recreational maps so that international users can understand the symbols. International visitors to outdoor areas may also have different experiences and background education in map usage in outdoor areas. Local and international visitors might perceive the design of both maps and trail parks differently.

Environmental Cues
Passini (1996) discussed the importance of signage design and building architectural design to prevent users from getting lost. Both factors can be enhanced to allow easier wayfinding for users. Misaligned and misplaced maps are also an issue of poor signage design that can mislead and confuse users (Levine, Marchon, & Hanley, 1984). If signs can be placed in the wilderness area at the correct location and alignment, users can use the signs as landmarks to orient themselves. Crampton’s (1992) conclusion on novices relying on route-knowledge for wayfinding is also another indication that creating environmental landmarks for novices might aid wayfinding. Perhaps signs can be placed at junctions of the trails; these will be strategic since junctions are points of decision-making where mistakes could be made (Passini, 1996). This is also useful to prevent wrong turns at junctions not shown on the map since there will be no signs at junctions between unnamed trails.

Based on the discussion above, we sought to investigate wayfinding performance in an outdoor trail network using different map designs with considerations of individual differences and presence of signage at the junctions. Specifically, we predicted that:

1. Shaded relief maps and schematic maps would lead to better wayfinding performance compared to contour maps.
2. Color maps would lead to better wayfinding performance compared to black-and-white maps.
3. The following user profile will be associated with better wayfinding performance compared to the contrasting user categories: Male, experience, local (versus international), and left-handed.
4. Environmental cues in the form of signs at junctions will lead to better performance compared to areas in which no environmental cues were present.

Method

Participants
Thirty-six participants were recruited from the local community of Blacksburg, Virginia. None of the participants had used a map or knew the trail names for that test area prior to participating in the study. There were 28 males and 8
females, ranging in age from 18 to 36 ($M = 23.5$, $SD = 3.78$). Participants reported their experience in map usage in outdoor areas (experienced or novice), their handedness (left or right), and culture (local or international) in a demographic questionnaire. Participants were asked to indicate if they have used a map in an outdoor area for more than two times. Participants were asked whether they considered themselves novice in hiking or orienteering. If they did not consider themselves novices, they were asked to explain why. The same questions were asked again in post-test questionnaire. Those who indicated they were novice in the final questionnaire were coded as novice and non-novice were coded as experienced. The participants were asked if they were native English speaker and where did they live for the past twenty years to determine their cultural background. Those who indicated they were native English speakers and had lived in United States for the past twenty years were considered local; otherwise, they were considered international.

There were 17 experienced map users and 19 novice map users. Fourteen of the 36 participants were local USA participants and 22 were internationals. The international participants consisted mainly of individuals from China (7), India (8), Thailand (2), and one each from Korea, Indonesia, Puerto Rico, Italy, and Ecuador. There were four left-handed participants. All participants had at least a high school education. Efforts had been made to counter balance the factors (e.g., to have equal number of experienced and novice map users) as far as possible. However, it was not possible to counterbalance all the factors due to the small number of volunteers within specific groups (e.g., few left-handed volunteers). The small number of total participants that can be handled given the limited resources also limited the study. A multiple regression design was used to cater to the unbalanced number of participants in each factor.

Maps and Study Area

The area of study was a forest trail network at Pandapas Pond in Jefferson National Forest near Blacksburg, Virginia. Participants were randomly assigned to one of six map conditions, created from 3 contour representations (contour lines, shaded relief, and schematic) by 2 color codes (color vs. black and white). For color maps, water and contour were colored blue and brown, respectively. The designated trail was highlighted yellow for all maps. The trails were coded with different types (e.g., dot-dash) and colors of lines to ensure that the trails were unique. As there were eleven labeled trails on the maps, a total of eleven colors was used for the trails in addition to the color black, which was used for the main road. The area of representation, labeling, and trail information were the same for all test maps. Information on the maps was based on a distribution map from the Blacksburg Ranger District for Poverty Creek and Gap Mountain Trails (Jefferson National Forest, 1999). The maps are printed on letter size paper (21.59 cm by 27.94 cm). Figures 1, 2, and 3 show the color contour, shaded relief, and schematic maps, respectively. Figure 4 shows the blown-up map of the route used for the study.
Figure 1. Contour map.

Figure 2. Shaded relief map.
Figure 3. Schematic map.

Figure 4. Blown-up map of the route used for the study. Junctions 3, 6 and 7 had directional signs posted at the junctions. Junctions 4, 5, and 6 had some side trails joining the junctions but not shown on the test maps. (SP = Start Point; EP = End Point; J1 to J10 = Junction 1 to Junction 10).
There were 10 junctions in the trail network, where 3 of the junctions had directional signs at the junction (junctions 3, 6, and 7). The signs consisted of trail names and directions of the trails intersecting the junction. Some of the trails on the ground were not marked on the test maps to reflect the information content on the distribution map. Junctions 4, 5, and 6 had unmarked trails intersecting the marked trails. This was to reflect realistic map usage since users of free distribution trail maps usually have to make decisions on the basis of outdated map information. Figure 5 shows some of photographs of the trails that were encountered by the participants.

**Questionnaire**

A retrospective think aloud method was used (Ericsson & Simon, 1984). The participants were interviewed after their trial to elicit their thinking processes during the wayfinding task. They were shown photographs of each junction and the blown-up map shown in Figure 4. For each junction and trail segment, they were asked to recall what they were thinking at that time and what information they used to make decisions. The same set of questions was used at each junction and segment, such as:

1. Tell me what you can remember thinking at Junction 1 (substitute with 1 to 10 for the respective junctions).
2. Tell me what information you used at this junction to make your decision about which path to choose.
3. Did you know you were lost (if the participant was lost)?

If the participants were not clear with their answers, more specific questions would be asked, such as:

1. Was there any particular information from the environment that helped you in making up your mind? (For example, stream, signage, trail shape, slope).
2. Was there any particular information from the map that helped you in making up your mind? (Trail labels on map, contour lines, color of trail, stream symbol).
3. Describe the process of how you made up your mind.

The interview data yielded qualitative results that helped to describe the thinking process of the participants. After the interview, the participants were administered a questionnaire to obtain subjective feedback and preferences. These questions are shown in Table 1. An open-ended question was used to obtain improvements based on their map usage experience during the trial.

**Procedure**

The participants were briefed on the purpose of the study and their informed consent was obtained. They were then given written instructions on the conduct of the study and randomly assigned one of the six maps. The participants were
Figure 5. Photographs of some of the trail junctions and signs at Junction 6. Note the differences in trail characteristics (e.g., gravel covered).
Table 1

<table>
<thead>
<tr>
<th>Question</th>
<th>Construct elicited by the question</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. How clear is the designated trail on the map?</td>
<td>Feature clarity</td>
</tr>
<tr>
<td>2. How clear are the water features on the map?</td>
<td>Feature clarity</td>
</tr>
<tr>
<td>3. Do you think you needed a compass for the hike you just completed?</td>
<td>Map usability</td>
</tr>
<tr>
<td>4. When you navigated the trail, did you rotate the map while you walked?</td>
<td>Mental rotation</td>
</tr>
<tr>
<td>5. If you were given other maps (from this selection of maps I am showing you, which would you prefer. (Participants were shown the contour, schematic, and shaded relief maps.)</td>
<td>Preference for map design</td>
</tr>
<tr>
<td>6. Did you lose your way during the hike? Is yes, why do you think you lost your way?</td>
<td>Problems faced during the wayfinding</td>
</tr>
<tr>
<td>7. Do you think there is anything that needs improvement on the map? List the improvement.</td>
<td>Improvements of maps</td>
</tr>
</tbody>
</table>

given a short practice session to familiarize them with thinking aloud. The practice session consisted of doing multiplication, solving anagrams, and counting rooms in their childhood house (Ericsson and Simon, 1984) while walking around a parking lot. After the practice session, participants were transported to the study area. The assigned map allowed them to orient themselves while on the highway to simulate would-be visitors visiting the trail. Upon arrival at the study area, the participants were briefed again on the instructions by the experimenters. An experimenter followed each participant to record the actions and verbal output using a video camera. No assistance was provided while the participants tried to navigate on a marked route on their assigned maps. The experimenter did not assist the participant unless there was an emergency or the participant was noticeably lost, such as walking on the wrong path for at least one minute without realizing their mistake. The experimenter carried a walkie-talkie to support communication in case of emergency. At the end of the route, the interview was administered to obtain information on what happened during the experiment followed by a questionnaire to obtain subjective feedback. The participants were then debriefed, compensated, and transported back to their point of origin.
Results

**Overall Performance**

The total time taken to complete the route (TotalTime), time to make a decision at each junction (DM), accuracy of decision-making at each junction (Accu), and the total time deviated from the route (TotalDev) were measured using predefined criteria applied to the video data. Lower TotalTime, DM, and TotalDev constitute better performance, whereas higher Accu implies better performance. The overall mean TotalTime was found to be 59 min 28 s ($SD = 423$ s). The mean time to make a decision at each junction is shown in Figure 6.

The total time used for decision-making (TotalDM) is the summation of DM1 to DM10. The mean TotalDM was found to be 334 s ($SD = 190$ s). The mean total time used for decision-making was about 9.5% of the mean total time taken to complete the route. The accuracy of decisions made at each junction was coded as Accu1 to Accu10 for Junctions 1 to 10 respectively, where a value of 1 represents a correct decision and 0 represents an incorrect decision. The total number of correct decisions made (TotalAccu) was computed for each participant and the mean TotalAccu was found to be 8.25 ($SD = 1.5$) out of a possible maximum of 10. This overall result indicates that the participants, on average, performed fairly well since there was an overall success rate of 82.5%. Most of the participants scored 6 or more correct junctions out of ten.

![Mean Time to Make a Decision at Each Junction](image)

*Figure 6.* Mean time to make decision at each junction. Note that Junctions 4, 5, and 6 took a longer time for decision making. Junctions 4, 5 and 6 had higher decision making times than the rest of the junctions.
The frequency distribution of the TotalAccu is summarized in Figure 7. The mean accuracy at each junction is summarized in Figure 8. Note that Junctions 4 and 5 had lower mean accuracy compared to the other junctions in Figure 8 and Junctions 9 and 10 had no errors.

**Figure 7.** Frequency distribution of participants with respect to the total correct decisions made participants. Two participants had 4 correct junctions; the rest of the participants had 6 or more correct decisions out of 10. Only eight participants obtained a full score of 10.

**Figure 8.** Mean accuracy of decision-making at each junction. Note that Junctions 4, 5, and 8 were having lower accuracy than the rest of junctions. All participants were able to correctly decide at Junctions 9 and 10.
The mean total time deviated (TotalDev) for all participants was 282 s ($SD = 234$ s). Junctions 4 and 5 had high decision-making times and low accuracy. The low wayfinding performance at Junctions 4 and 5 may be due to discrepancies in map information. Note that Junctions 9 and 10 appeared to be very easy as all participants managed to decide quickly and accurately.

**Multiple Regression**

TotalTime and TotalDev were regressed with the following predictors:

- shaded map (“1” for shaded map, “0” for non-shaded map),
- schematic map (“1” for schematic map, “0” for non-schematic map),
- color map (“1” for color map, “0” for black and white map),
- gender (“1” for female, “0” for male),
- handedness (“1” for left-handed, “0” for right-handed),
- culture (“1” for international, “0” for local),
- experience (“1” for novice, “0” for experienced).

DM was regressed with the same predictors as above in addition to signage presence (“1” for junction with sign, “0” for junction without sign). Accu was regressed using logistic regression with the same predictors as DM. The regression results are summarized in Tables 2, 3, and 4.

Results showed that all predictors were non-significant for TotalTime and DM (see Tables 1 and 2). However, cultural difference (Culture) was found to be a significant predictor for Accu and TotalDev at $p < .01$ level, and signage presence (Sign) was found to be a significant predictor for Accu at $p < .01$ level (see Tables 1 and 3). International participants made more mistakes in decision-making at the junctions, $B = -1.29$, $Exp(B) = .28$. Local participants were $3.57 (1/0.28)$ times more likely to make a correct decision at a junction compared to international participants. Junctions with signs increased the likelihood of correct decision-making by participants, $B = 1.31$, $Exp(B) = 3.71$. Signage presence increased the likelihood of correct decision-making by 3.71 times. The mean of TotalDev for locals was 114 s ($SD = 133$ s) whereas for internationals, the mean was 389 s ($SD = 223$), $t(34) = -4.63$, $p < 0.001$. This is consistent with the accuracy measure, which showed that internationals tended to make more mistakes and hence spent more time deviating from the route.

There were no map design differences, gender differences, experience differences, and handedness differences in wayfinding performance for the task used in this study.

**Retrospective Interview Results**

The data from the retrospective interview and video recordings were analyzed and compared to ensure that the information agreed between the two datasets. In general, the data from the retrospective interview matched the verbal protocol
Table 2

Summary of Simultaneous Regression Analysis for Variables Predicting Total Time of Completion of Test Route (TotalTime) and Total Time of Deviation from Correct Route (n = 36)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Sr²</th>
<th>F(sr)</th>
<th>B</th>
<th>SE B</th>
<th>ß</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total time of completion (TotalTime)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shaded</td>
<td>0.03</td>
<td>1.02</td>
<td>183.73</td>
<td>181.83</td>
<td>.20</td>
</tr>
<tr>
<td>Schematic</td>
<td>0.00</td>
<td>0.00</td>
<td>-7.61</td>
<td>176.28</td>
<td>.01</td>
</tr>
<tr>
<td>Color</td>
<td>0.01</td>
<td>0.38</td>
<td>-90.03</td>
<td>146.54</td>
<td>.11</td>
</tr>
<tr>
<td>Sex</td>
<td>0.00</td>
<td>0.07</td>
<td>52.77</td>
<td>193.92</td>
<td>.05</td>
</tr>
<tr>
<td>Experience</td>
<td>0.06</td>
<td>2.11</td>
<td>228.07</td>
<td>156.95</td>
<td>.27</td>
</tr>
<tr>
<td>Culture</td>
<td>0.05</td>
<td>1.88</td>
<td>204.28</td>
<td>149.01</td>
<td>.24</td>
</tr>
<tr>
<td>Handedness</td>
<td>0.00</td>
<td>0.01</td>
<td>-25.79</td>
<td>236.27</td>
<td>.03</td>
</tr>
</tbody>
</table>

Full model: Intercept = 3300.13, $R^2 = .19$, adjusted $R^2 = -.01$, $p = .48$

<table>
<thead>
<tr>
<th><strong>Total time deviation from correct route</strong></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Shaded</td>
<td>0.0006</td>
<td>0.028</td>
<td>-15.07</td>
<td>86.93</td>
<td>.03</td>
</tr>
<tr>
<td>Schematic</td>
<td>0.0364</td>
<td>1.722</td>
<td>-109.83</td>
<td>84.27</td>
<td>.22</td>
</tr>
<tr>
<td>Color</td>
<td>0.0029</td>
<td>0.137</td>
<td>25.84</td>
<td>70.06</td>
<td>.06</td>
</tr>
<tr>
<td>Sex</td>
<td>0.0059</td>
<td>0.279</td>
<td>-48.62</td>
<td>92.71</td>
<td>.09</td>
</tr>
<tr>
<td>Experience</td>
<td>0.0038</td>
<td>0.180</td>
<td>31.87</td>
<td>75.04</td>
<td>.07</td>
</tr>
<tr>
<td>Culture</td>
<td>0.28***</td>
<td>13.19</td>
<td>256.66</td>
<td>71.24</td>
<td>.54***</td>
</tr>
<tr>
<td>Handedness</td>
<td>0.0051</td>
<td>0.241</td>
<td>55.40</td>
<td>112.96</td>
<td>.08</td>
</tr>
</tbody>
</table>

Full model: Intercept = 141.39, $R^2 = .40$, adjusted $R^2 = -.25$, $p = .03$

Note: $sr^2$ = semipartial correlation coefficient, indicating the unique variance accounted for by the predictor beyond the variance accounted for by the other predictors; $F(sr)$ = test for reliable contribution of the predictor; $R^2$ = squared multiple regression coefficient, indicating total variance in criterion variable accounted by the predictors in the regression equation; $B$ = multiple regression coefficient; $\hat{\beta}$ = standardized multiple regression coefficient. ***$p < .001$.

...from video recording data. The responses were tabulated based on frequency for each of the junctions and trail segments. Note that participants at times gave more than one response, and some responses were affective in nature (e.g., “Confident that this was the correct trail”). These responses gave the information on how the participants used the cues available to them and helped to illuminate the mental processes used by the participants. Table 5 shows an example of the most frequent responses for Junction 4.
Table 3
Summary of Simultaneous Regression Analysis for Variables Predicting Time of Decision-making (DM) at Each Junction (n = 360)

<table>
<thead>
<tr>
<th>Variable</th>
<th>sr²</th>
<th>F(sr)</th>
<th>B</th>
<th>SE B</th>
<th>β</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shaded</td>
<td>9.00E-04</td>
<td>0.32</td>
<td>-3.79</td>
<td>6.74</td>
<td>-.04</td>
</tr>
<tr>
<td>Schematic</td>
<td>1.90E-03</td>
<td>0.69</td>
<td>-5.37</td>
<td>6.54</td>
<td>-.05</td>
</tr>
<tr>
<td>Color</td>
<td>8.30E-03</td>
<td>2.99</td>
<td>-9.35</td>
<td>5.44</td>
<td>-.09</td>
</tr>
<tr>
<td>Sex</td>
<td>3.80E-03</td>
<td>1.37</td>
<td>8.40</td>
<td>7.19</td>
<td>.07</td>
</tr>
<tr>
<td>Experience</td>
<td>1.10E-03</td>
<td>0.40</td>
<td>5.75</td>
<td>5.82</td>
<td>.06</td>
</tr>
<tr>
<td>Culture</td>
<td>3.00E-03</td>
<td>1.08</td>
<td>5.68</td>
<td>5.53</td>
<td>.06</td>
</tr>
<tr>
<td>Handedness</td>
<td>2.90E-03</td>
<td>1.05</td>
<td>-8.88</td>
<td>8.76</td>
<td>-.06</td>
</tr>
<tr>
<td>Sign</td>
<td>3.00E-04</td>
<td>0.11</td>
<td>1.85</td>
<td>5.73</td>
<td>.02</td>
</tr>
</tbody>
</table>

Full model: intercept = 34.12, $R^2 = .02$, adjusted $R^2 = .002$, $p = .36$

Note: $sr^2$ = semipartial correlation coefficient, indicating the unique variance accounted for by the predictor beyond the variance accounted for by the other predictors; $F(sr) = test$ for reliable contribution of the predictor; $R^2 = squared$ multiple regression coefficient, indicating total variance in criterion variable accounted by the predictors in the regression equation; $B = multiple$ regression coefficient; $\beta = standardized$ multiple regression coefficient. **p < .001.

Table 4
Summary of Simultaneous Logistic Regression Analysis for Variables Predicting Accuracy of Decision-making (Accu) at Each Junction (n = 360)

<table>
<thead>
<tr>
<th>Variable</th>
<th>B</th>
<th>SE B</th>
<th>Exp(B)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shaded</td>
<td>-.29</td>
<td>.36</td>
<td>.75</td>
<td>.42</td>
</tr>
<tr>
<td>Schematic</td>
<td>.43</td>
<td>.38</td>
<td>1.53</td>
<td>.26</td>
</tr>
<tr>
<td>Color</td>
<td>.04</td>
<td>.30</td>
<td>1.04</td>
<td>.90</td>
</tr>
<tr>
<td>Sex</td>
<td>.35</td>
<td>.41</td>
<td>1.42</td>
<td>.39</td>
</tr>
<tr>
<td>Experience</td>
<td>-.20</td>
<td>.31</td>
<td>.82</td>
<td>.53</td>
</tr>
<tr>
<td>Culture</td>
<td>-1.29***</td>
<td>.37</td>
<td>.28</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Handedness</td>
<td>-.28</td>
<td>.43</td>
<td>.76</td>
<td>.52</td>
</tr>
<tr>
<td>Sign</td>
<td>1.31**</td>
<td>.41</td>
<td>3.71</td>
<td>.001</td>
</tr>
</tbody>
</table>

Full model: intercept = 2.20, Cox & Snell $R^2 = .09$, $\chi^2 (8, N = 360) = 34.02$, $p < .0001$

Note: Cox & Snell $R^2 = squared$ multiple regression coefficient, indicating total variance in criterion variable accounted by the predictors in the regression equation; $B = multiple$ regression coefficient; $Exp(B) = Odds$ ratio of the predictor, the likelihood. **p<.01; ***p<.001.
Table 5.
Retrospective Responses for Decision Making at Junction 4

<table>
<thead>
<tr>
<th>S/No</th>
<th>Retrospective Response</th>
<th>Total (N=36)</th>
<th>Local (14)</th>
<th>Int (22)</th>
<th>Exp (19)</th>
<th>Nov (28)</th>
<th>M (8)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Turned right according to map</td>
<td>18</td>
<td>9</td>
<td>9</td>
<td>11</td>
<td>7</td>
<td>14</td>
</tr>
<tr>
<td>2</td>
<td>Trail was not on map</td>
<td>11</td>
<td>7</td>
<td>4</td>
<td>7</td>
<td>4</td>
<td>10</td>
</tr>
<tr>
<td>3</td>
<td>Not sure where present location</td>
<td>9</td>
<td>7</td>
<td>2</td>
<td>3</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>4</td>
<td>Thought was at Jn 6</td>
<td>7</td>
<td>2</td>
<td>5</td>
<td>2</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>5</td>
<td>Too early to go back pond</td>
<td>7</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>6</td>
<td>Followed double paint mark on tree to turn right</td>
<td>5</td>
<td>5</td>
<td>0</td>
<td>3</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>7</td>
<td>Just keep walking &quot;straight&quot;</td>
<td>4</td>
<td>0</td>
<td>4</td>
<td>1</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>8</td>
<td>Thought junction was further</td>
<td>4</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>9</td>
<td>Checked that it was at top of hill to match with map</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>10</td>
<td>Not sure of distance traveled</td>
<td>4</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>11</td>
<td>Left trail looked more conspicuous</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>12</td>
<td>Distance walked was correct to make right turn</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>13</td>
<td>Not using map</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>14</td>
<td>Turn left to check T1 and confirm it was wrong</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

Int = Internationals; Exp = Experienced; Nov = Novice; M = Male; F = Female

To illustrate the trail cues that were available to the participant, Figure 9 shows two locations on the trail that correspond to Junction 4 on the map. At point 1, there were two trails that branched to the right and left. Both trails would bring the participant back to the main trail, although the designated trail on the map is to the left. Note that the red dotted trails on the map were not shown on the participants’ maps, as the red dotted trails were pseudo-trails created by other users seeking shortcuts. At point 2, the correct trail was the one on the right, marked by the white arrow (see Figure 9). More than half of the participants (18 participants) turned right here based on the map information as shown in Table 5; many of them realized that the side trails were not on the map. Those who gauged their time of travel seemed to realize that it was too early to turn left back to the pond, and used multiple cues such as elevation, double paint marks on trees, distance traveled (related to time too), and trail conspicuity, to aid them in decision making. Those who had problems at this junction thought they were at Junction 6 (item 4 in Table 5) and mentioned they were not sure of their present location (item 3 in Table 5). The presence of
unmarked trails caused these participants to misjudge their location and participants tried to feature-match the map with the ground by looking for trail features on the map that branched into two trails. The only other junction on the participants’ maps that branched out to left and right trails was Junction 6 (compare map in Figure 9 and Figure 4). For each junction, such detailed analysis was conducted to understand why some participants were successful despite ambiguities while others failed (see Soh, 2002). The responses obtained from the participants were diverse, as expected, due to individual differences in their experiences and outlook towards the hike. However, there were some indications of the general strategies used by the participants when wayfinding in the natural environment.
To summarize the retrospective interview data, it was found that participants relied mainly on the principles of orientation to hike with the map (Levine, 1982), and structural matching (Levine, 1982) when there was confusion due to ground and map mismatches. The participants would rotate their maps to the direction they were moving and with one known point, utilized the principle of orientation to follow the map (Levine, 1982). When there were ambiguities, such as unmarked trails, the participants tried to match the map with the structure of the ground (principle of structural matching). Those who only relied on the structural matching principle were likely to misjudge the junction with incorrect but similar features on the map, causing them to make incorrect decisions. For those who judged the distance they traveled (or time spent walking) correctly, in addition to using the principle of structural matching, there was higher probability that they were correct with their decision. However, even for those who were experienced hikers who knew how to judge distance traveled, they still seemed confused when the environmental cues largely contradicted the map information. Examples of these gross contradictions included unmarked trails, wrongly marked blazes, or main trails that appeared to be covered with more leaves causing them to appear to be less conspicuous or more similar to side trails. Those junctions with signs, when sighted, offered the best cues for the participants, who confirmed their current locations and followed the directions indicated on the signs. The interview data also provided evidence that participants relied on landmark information such as the pond, the parking lot, creeks, and major bends of trails as milestones to confirm their location. Other environmental cues were also used, such as trail width, trail usage, blazes, but the participants interpreted such cues differently. For example, different participants could judge the same trail as a major trail or a minor trail. Participants who made a wrong decision at a junction were not aware they had made an incorrect decision. These participants tended to keep walking until the experimenter stopped them or until anticipated landmarks did not appear.

Post-interview Questionnaire Results
Of the 36 participants, 2 of the participants found the designated trail on the map “Very Clear”, 22 found it “Clear” 11 found it “Unclear”, and 1 found it “Very Unclear”. In addition, 66.67% of the participants found the designated trails in the map “Very Clear” and “Clear”, compared to 33.33% in the “Unclear” and “Very Unclear” group ($\chi^2(1) = 4.00, p = .046$, significant at .05 level). Sixty-one percent of the participants found the water features to be “Clear” and “Very Clear” compared to 38.89% of participants responding that the water features were “Unclear” or “Very Unclear” (13 “Unclear”; 1 “Very Unclear”). There was no significant difference at the .05 level between number of participants choosing “Clear/Very Clear” and “Unclear/Very Unclear” ($\chi^2(1) = 1.78, p = .18$) for the water features. The map features, in general, were clear to the
participants although a substantial proportion of participants did find the designated trail and water features to be unclear.

When asked if they needed a compass for the hike they just completed, significantly more participants replied “No” (66.67%) than participants who replied “Yes” (33.33%; $\chi^2(1) = 4.00, p = .046$). The reasons given by participants who replied “No” were:

1. Easy to follow signs and map (Frequency = 9)
2. Use landmark for direction (5)
3. Use sun for direction (2)
4. Short trail, easy, no need for compass (4)
5. Map not accurate enough to use compass (3)
6. Did not know how to use compass (1)

Those who replied “Yes” felt that the compass could help them with directions since the map was not accurate enough (Frequency = 9) and the sun was not always available to indicate direction (Frequency = 3).

When asked to compare the three different contour representation maps, 22 (61.11%) of participants preferred a contour map compared to 12 (33.33%) of participants who preferred a shaded relief map ($\chi^2(1) = 8.33, p = .004$). Only 2 (5.56%) of participants preferred a schematic map ($\chi^2(2) = 16.67, p < .001$). Most participants seemed to prefer to have contour information where more participants chose the contour map due to familiarity to the representation of contour lines. Those who chose the shaded relief map reported that the shaded relief map was easier to read compared to the contour map.

All participants rotated their map when they navigated. A majority of the participants rotated the map to the direction of movement (29 of 36 or 80.6%). Four of the participants rotated the map to a northerly direction using the sun as an indication (11.1%). One of the participants rotated the map to match the landmarks on the ground.

Seven participants reported that they did not lose their way during the experiment although “officially” eight participants were perfect in their accuracy scores. These data, when corroborated with observational data from video recordings, showed that some participants might not be totally aware of the correctness of their actions. Two of the seven participants who thought they did not lose their way, made mistakes at one of their junctions. One of them walked into a forest trail (at Junction 4) thinking that he would be able to join back to the main trail on his right. The experimenter stopped him halfway, as the forest trail in fact would not join back. However, the participant did not realize his mistake and assumed he was correct throughout the experiment. The other participant made a mistake at Junction 8, but knew that both trails at Junction 8 would bring him back to the endpoint. So he did not consider himself lost.

Three other participants, however, considered themselves lost although they were officially making all the correct decisions at all the junctions. These three participants turned correctly at a prior junction, but after walking on the correct
trail for some time, they lost confidence and turned back to check their previous decisions. Two of them occurred at Junction 5 where the correct trail had no blazes causing the participants to turn back to the trail where blazes were marked incorrectly on the trees. One of the three participants was at Segment 5 after turning correctly at Junction 4. He turned back as he was not confident of his earlier choice thinking he should turn left at Junction 4. Technically, these three participants were considered making correct decision at their respective junctions of confusion. However, they considered themselves lost, as they were not sure of their locations. Hence, only five participants can be considered to have known their locations the entire time and made all the correct decisions based on the specified experimental route ($\chi^2(1) = 18.78, p < .001$).

When asked why they thought they lost their way if they reported being lost, the following reasons were given by the participants (some participants gave more than one reasons):

1. Trails not shown on map (Frequency = 13)
2. Not attentive (6)
3. Unclear map (5)
4. Misjudged distance (5)
5. Wrongly marked blazes (4)
6. Not sure how to use map (3)
7. Not enough signs (2)
8. Lack contour (1)
9. Small map scale (1)
10. Trails geometry did not match ground (1)

The reason quoted by participants with the highest frequency was that all trails were not shown on the map causing them to misjudge the direction to turn. All participants thought the maps needed more improvement. Types of improvements suggested included:

1. Update map information (Frequency = 18)
2. Design better representation of contours: need higher resolution; symbol for hill; contour and trails confusion due to color use; (12)
3. Use a larger map scale to show more details (6)
4. Better representation of the map features: width of trails shown on map; clearer water features; better legend design (5)
5. Use colored maps (3)
6. Show distance on trail (2)
7. Show vegetation (1)
8. More signs on trails (1)
9. Give instructions on how to use maps (1)
Discussion

The three different representations of contours, namely, no contour information (schematic map), contour map, and shaded relief map were not found to be significant predictors of the total time of completion, time for decision-making, accuracy of decision-making, and time deviated from routes using regression analyses. These results mirrored Delvin and Bernstein’s (1997) kiosk-based wayfinding study, where the level of detail neither enhanced nor decreased performance. However, participants reported a preference for maps with contour information compared to shaded relief and schematic maps (in decreasing order). This can be explained by the fact that the shaded relief map is a newer format that few people are familiar with compared to contour maps. The shading representation also lacked detailed elevation information compared to the contour map, which experienced participants needed to compare the changes in elevation. Some trails were not shown on the map, which confused the participants and might have caused participants to look for additional contour information to confirm the terrain. It can be argued that outdoor maps should have no contour information, as it was not shown to be advantageous to have contours. However, contour information would be helpful to experienced users or when trail information is outdated, given that users could at least rely on terrain elevation cues to orient themselves.

Map color was not shown to be a significant predictor of wayfinding performance in the multiple regression analyses. This somewhat mirrored Devlin and Bernstein (1997) and the Garland, Haynes, and Grubb (1979) findings that color maps did not greatly enhance wayfinding. This shows that black and white maps can be used, if designed clearly, since actual wayfinding was not affected by the color of the map. However, color was observed to allow better discrimination of map features such as water features.

Gender of participants was not found to be a significant predictor of wayfinding performance in this study. The results contrasted with a number of other studies that found better wayfinding performance in males (Delvin & Bernstein, 1995, 1997; Galea & Kimura, 1993; Malinowski & Gillespie, 2001; McGuiness & Sparks, 1983; Miller & Santoni, 1986; Ward, Newcombe, & Overton, 1986). Most previous studies were laboratory-based or static studies that might demand more spatial cognition than realistic wayfinding tasks. One exception was a study by Malinowski and Gillespie (2001), where male participants were better than female participants in a real-world orienteering task. In this study, however, there was less demand on spatial abilities since the participants were trail bound and the choices available for decision-making were more limited compared to Malinowski’s and Gillespie’s study. It would be expected that males and females would perform equally well in a trail-bound wayfinding task such as the one in this study. This study did not resolve the disagreements regarding gender differences in wayfinding. More real-world wayfinding studies are required.
It was surprising that no experience differences were identified. Experienced participants were expected to do better than novices. However, in this study, there was a confounding factor due to inaccurate environmental cues. Blazes, which were paint marks on trees to denote main trails, were marked on a trail not shown on the map at Junction 5. The erroneous cues caused some of the experienced users to follow the blazes rather than the trail that was correct, causing more errors by experienced users. It was also possible that self-reported map usage experience might not be reliable, as people might over-rate or under-rate their experience. Another possible explanation was that skills required for trail-bound wayfinding might be basic, such that novices and experienced participants were able to perform similarly. Thorndyke and Stasz (1980) found that performance of map encoding and recall of map information were not dependent on the experience of the participants in terms of map usage. Instead, performance was due to the learned procedures that participants used when learning the map, which in turn, depended on the background of the participants. Perhaps, novice participants, albeit less experienced, might have learned some basic adaptive strategies that enable them to perform as well as the experienced participants.

Cultural difference was found to be a significant predictor of the accuracy of the decision-making and time deviated from the route, although not significant in predicting the time used for decision-making at the junctions and total time of completion. International participants were observed to have more difficulties understanding trail names and reading the signs. They also tended to miss more trail signs than local participants. Saku (1992) found that experience in geography and formal instruction resulted in better map interpretation for higher-level tasks such as reading contour lines. International participants might not be as well equipped by their respective educational systems to use maps and navigate recreational trails as effectively as the locals. It is also likely that maps designed for outdoor recreation areas were designed for target users from the USA, rather than from countries outside the USA. The local participants may also be more familiar with the way the signs were labeled and more familiar with the forest system. International participants were sometimes confused with the way the trails were named such as the “Joe Pye Trail” or the “Snake Root Trail”, and spent more time reading the signs and maps. As the international participants were mostly students from the local area, it was unlikely that they have language problems since they were qualified to study in the United States. In addition, the signs only consisted of trail names and arrows; they were not taxing the participants’ language abilities. Further study in this area would be required to fully understand the contributions of cultural differences.

Contrary to Delvin and Berstein’s (1997) study, there was no significant difference in wayfinding performance due to the handedness of the participants. This could be attributed to relatively few left-handers in the study and relatively lower demand in spatial manipulation or abstraction required in the task.
Signage presence was found to be a significant predictor of accuracy but not of time for decision-making. It was expected that with signage, participants could decide on which path to choose at a faster rate. However, this study demonstrated that sign design was confusing to some participants as two of the signs were showing orthogonal directions of a trail at the bend. Participants expected trail names to be along a straight path or end at the intersection rather than turning. The signs were purposely designed to blend with nature to reduce obtrusiveness to the natural environment. This low saliency design caused several participants to miss the signs and experienced more difficulties reading the signs even when they saw the signs. Smith-Jackson and Hall (2002) found that park visitors supported trail and campground signs that were highly salient (e.g., bright colors) and that contrasted with the natural hues found in outdoor recreation areas.

In some instances, information on the signs was not sufficient and resulted in conflicts with users’ expectations. More time was used to interpret the signs than was expected. Some junctions without signage were inherently easy due to prominent landmarks and environmental features, which participants spent lesser time when compared to junctions with signs. However, most people were able to choose correctly at junctions with signs if they saw the signs. Well-designed signs should be used as much as possible to prevent people from getting lost in the trail park (Levine, 1982; Levine, Marchon, & Hanley, 1984; Passini, 1996). Participants appeared to use more environmental cues than were considered in the experiment, such as the type of trees, the characteristics of the trails, the presence of creeks and pond, sounds from a nearby shooting range and highway, and trail blazes. Signage may not be the only environmental cue crucial to outdoor wayfinding.

The strategies used by the participants show that they usually employed simple processes such as orienting principle and structural matching. Participants were not very good at judging distance traveled and became confused when information between the map and trail was contradictory. When the participants encountered unmarked trails, the directional difference between the trails might not always be distinct enough to use the directional information on the map to judge which trail corresponds to the correct trail on the map. Assistance to users who are novices at wayfinding should include information that helps them correctly match the structures between map and the ground. Map information should be regularly updated to support structural matching. Signage with additional distance information can be used to aid structure matching and distance judgment. Maps with different magnifications and more in-depth details, such as type of vegetation, may also provide more matching features for map users.

Note that the predictors selected for this study have low contributions to the variance of wayfinding performance in this study. Only 19% of the total variance in the regression model accounted for total time of completion; 2.4% was accounted for by time for decision making; 9.0% was accounted for by
accuracy of decision making (using Cox and Snell $R^2 = 0.090$); and 39.8% was accounted for by time deviated from route. In Malinoski and Gillespie’s (2001) real world wayfinding study, their predictors (sex, self reported map use, math scores, and experience) accounted for 14% of the variance in the correct number of points found during wayfinding. Malinoski and Gillespie (2001) commented that although their findings validated laboratory-derived predictors of spatial abilities, their predictors did not account for a high proportion of the variance on their wayfinding task. These researchers suggested that “more real-world validation and replication needs to be done to find new explanations” (Malinoski & Gillespie, 2001, p. 81) for the unaccounted variance. This study supports Malinoski and Gillespie’s findings. As this study only had 36 participants, more participants and a balanced design in the independent variables such as gender and handedness, might improve the reliability of the findings. More real-world studies should be conducted to elucidate the factors as yet not accounted for that affect wayfinding. Observations during the experiment indicated that participants tend to use more environmental cues, such as blazes, sounds, and trail appearances, than those reflected on the maps. More environmental factors and wayfinding patterns and assumptions should be investigated, and a cognitive or mental models approach should be used to interpret the results.

Implications

Map designs in this case showed no objective differences in wayfinding, although subjectively, contour maps were preferred and color maps can improve map feature discrimination. A simpler and cheaper monochrome map might suffice for trail-bound wayfinding, as there was no objective difference in performance. It was found that those junctions with missing information might cause more errors and more time to decide, for example, Junctions 4 and 5. Maps should be regularly updated as trails in the outdoor recreational areas can change due to changes in usage patterns. For example, new trails (or pseudotrails) created by cyclists or hikers cutting through vegetation need to be addressed by finding methods to eliminate improper usage and repairing the trampled landscaping of those areas. If maps have less information, such as no contour lines, then the trail information should be more accurate and updated to prevent confusion. Otherwise, contour information should be incorporated to aid wayfinding as users can confirm their locations by comparing terrain.

Individual differences such as gender, handedness, and experience were not as crucial in this task although cultural difference was significant in accuracy and time deviated from route. More in-depth study would be required to fully understand the difference due to culture, as there are many international visitors to the outdoor recreational areas. Additionally, more real-world studies should be replicated to investigate if individual differences found in static map studies were relevant to day-to-day practical wayfinding tasks. It should also be noted that the mean age of this participant sample was 23.5, which is a relatively
young sample. Users of outdoor recreation areas may be relatively older, and because of age-related cognitive and sensory changes, may have more difficulty using maps that are inconsistent or not updated or signs that are difficult to see or comprehend. Thus, it is important for future studies in this area to examine age-related differences, and to determine the extent of hazards to older hikers that may be introduced by poor environmental cues.

Signage presence might be a good solution to prevent wayfinding problems in outdoor areas. More in-depth study into sign design is required to obtain better design guidelines to balance functionality and the natural aesthetic. It is also important to translate study results to specific user requirements and engineering and design guidelines to support safe and pleasurable experiences in outdoor recreation. For example, signage placement, content, and salience should be specified so that uniform and user-centered designs will be implemented in outdoor recreation areas. Map designs should also be specified using a human factors approach that relies on what is known about the capabilities and limitations of the target users.

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References


