

# Indoor Wayfinding Using Interactive Map

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**Abstract**—This study explored the use of interactive map for an academic library building. An interactive map was developed for six floors of the building. Participants used the map on a mobile device to conduct four different wayfinding tasks. A mobile eyetracking system was used to record gaze information that participants viewed. The gaze data were analyzed quantitatively and qualitatively using Begaze software. The results revealed that there were some trends. Individuals who were familiar with information technology devices were more successful in wayfinding making less error and hesitation. Individuals who had better sense of direction were more successful as well. However, familiarity with the building did not seem to be making a difference. Some design implications for interactive map design were suggested. The areas that are not open to public should have more explicit cues that the areas are not accessible such as crossing out the area.

**Index Terms**—Indoor navigation, wayfinding, mobile map, eyetracking, library.

## I. INTRODUCTION

This study aimed to explore library wayfinding. Wayfinding has a dynamic relationship to space [1]. It can be complex and challenging when individuals have limited physical or perceptual capabilities. It is a spatial problem solving process that requires three major steps: decision making, decision executing, and information processing. And so, in order to make wayfinding easier for building users, designers and planners should understand how building users perceive, interpret, and process the spatial information to find their destinations. Difficulty with indoor navigation due to poor facilities planning can lead to stress and frustration which will decrease use of buildings and negatively affect the accessibility and safety of users [2]. Library wayfinding is often very challenging because book stacks and rows of desks and chairs create numerous aisles, creating many different route choices.

As more indoor map applications are becoming available on mobile devices, more people can plan their routes before executing wayfinding in buildings, similar to road travelers using the GPS system in their car or mobile devices. Buildings now have indoor floor plans or maps on their websites so that visitors can plan their route beforehand. The Google indoor maps application is available for visitors and offers geographic location information instantly. Airports are good examples of this trend. Most airports include maps of their facilities their website. Some airports incorporate interactive features so that it is more user-friendly and

therefore easier to plan their routes ahead of time.

However, it is also true that indoor maps can be difficult to read or understand. The maps that utilize the GIS system do not always provide accurate information. This causes visitors feel frustrated as they find wayfinding difficult because the system lags in terms of accuracy and reliability.

Many academic libraries have made interactive maps available on their websites. However, those maps are often not user-friendly and create frustrations to users as in the airport example. This study conducted wayfinding tests in an academic library in North America. Other academic library interactive maps were tested and analyzed by investigators. In addition, a survey with a questionnaire was conducted in the library in order to understand wayfinding difficulties. Based on the results from those two methods, an interactive map for the library was developed.

This study's goal was to examine interactive map uses on mobile devices, difference between route planning on the map and the actual wayfinding performance, hesitation behavior, and success/fail in wayfinding behavior. This study sought to address design issues through examinations of map design that is used in this study focusing on design features that will enhance wayfinding in library.

## II. LITERATURE REVIEW

### A. Library Wayfinding

As academic libraries have multiple floors and sometimes multiple buildings integrated, navigation through these buildings can be both challenging and frustrating. In recent decades, libraries are undergoing rapid changes [3]. Modern libraries offer technology services such as computer in addition to traditional library services such as book stacks and quiet study areas. These added services make wayfinding more complicated as there are more areas that are included in the building. There are wayfinding aids including signs, maps and directories, service points, and landmarks that can be designed and made available to help navigation [4].

Library wayfinding has been studied for topics such as wayfinding performance tests [2], [4], [5], wayfinding aids [6], [7] and satisfaction with wayfinding [8]–[10]. Depending on the topics of wayfinding studies, various methods were used including observations, space syntax analysis, and survey.

When results from observations were compared to survey results, it was found that participants rarely mention the help of physical wayfinding resources such as signs and directories while they mentioned library staff help much more frequently when it was used [4]. Participants in the same study requested more wayfinding aids such as signs and maps throughout the building.

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Wayfinding observations also revealed that certain routes are much more popular than other routes [2]. That is, 22 out of 195 possible entry routes were used by 75% of the observed cases. Thus, it will be important for library administrations to identify high-traffic areas and pay special attention to those areas in order to arrange wayfinding resources more effectively. The information may offer library planners and designers critical design inputs as they can consider design efforts such as widened corridors, aisle widths, and unobstructed visual accessibility to signs in these areas [2].

Library layouts have three critical environmental aspects that affect library wayfinding: visibility, layout complexity, and connectivity [7]. Visibility offers visual access to an entire floor from all accessible locations. Some library areas that include tall furniture, such as book stacks or walls for different enclosed spaces, have low visibility which will lead to less effective wayfinding. Layout complexity can be evaluated by the total number of intersections and connected paths in between intersections. Connectivity is assessed by the axial links that pass through spaces on an axial map. Results of the study revealed that layout complexity may be the most critical environmental factor that affects wayfinding. Even individuals who are very familiar with the library have difficulties in wayfinding when an area in the library has a high layout complexity. Furthermore, the layout complexity is related to visibility and connectivity; a higher layout complexity is associated with a lower visibility and connectivity. Along with these environmental factors, wayfinding aids such as signs and maps are important help for wayfinding.

Ref. [3] also highlighted the importance of directories in entrance and exit areas. They also noted that the use of signages to identify main areas and the use of well-located maps in entrance areas were helpful.

It is interesting to note that [10] claimed that library users are not successful in finding what they are searching for. They suggested that improving catalogue usability will help the situation. In addition, they claimed that special collection areas only confuse library users. Another study by a multidisciplinary research team suggested using wayfinding software on mobile devices to facilitate wayfinding for library users. Although they did not really discuss their own development of the software, they shared the challenges in the development of a novel technology and questions that can be raised prior to the development [11].

### *B. Eyetracking for Wayfinding*

The eyetracking system has been used in psychology and has become more accurate and convenient due to the development of modern technology [12]. Although it was a laboratory-based test in the past, hardware-based mobile eyetracking systems are developed and popularly used today [13]. The system has been recognized as a data collection tool that is designed for user interface for 3D interaction, and is based on the idea of monitoring the users' views towards important locations and tracking the shift of their visual attention [14]. Although it has cost, limited accessibility, calibration problems, and time-consuming limitations [14], [15], eyetracking systems continued to grow in its use and be

used for studies in the field of human computer interaction.

The eyetracking system is used to collect eye movement data. Common metrics from the eyetracking system are fixation count, fixation duration, fixation pattern, and time to first fixation. This data is used as an overall indicator of the efficiency of individuals' performances in wayfinding tasks [16], [17]. The system also records pupil diameter and saccades multiple times per seconds within a session [18]. Fixation refers to the moment when the eyes are relatively still, and saccade refers to rapid eye movement. With an eyetracking system, hypothetical eye movements are recorded in sequences. Common belief is that users perform wayfinding through visual analytic actions on interactive visual displays.

Researchers use the eyetracking system based on common assumptions: more fixations indicate less efficient search strategy and longer fixations indicate difficulty with the display. In addition, scan paths address what, where, how often, and how long people look [18]. The heat map aggregates gaze path and spatial similarities [19]. The scan path is utilized to determine visual search tasks and areas of interest that may indicate search patterns or search structure—whether it is efficient or inefficient search, or whether it is active or less active search [16].

The recorded video data from the eyetracking system are converted into both quantitative and qualitative data. For example, the number of error behaviors based on the route planning and route following information, number of re-orientation, and planning duration are counted from the video data. Individuals' wayfinding and navigation behaviors can be qualitatively inspected by analyzing where and how they make errors. Fixation duration and fixation counts are quantified and specific patterns are qualitatively explained. The eye movement information also reveals the perceptual and cognitive processes of wayfinding [20].

The eyetracking system can provide information about how individuals use the mobile interactive map, how they navigate and identify locations, and what their orientation patterns and strategy may be.

## III. RESEARCH METHODS

### *A. Participants*

Eight subjects (four male, four female) participated in the test through a mailing list. The participants were 18 to 35 years old ( $M = 21.75$ ). Each participant spent about 90 minutes in the study and received a \$30 dollar gift card as a reward.

### *B. Materials*

An interactive library map of a university main library was developed for the study. The library was renovated and expanded in 1999 and is 336,000 square feet in six floors. The library is a popular location for studying, doing research, relaxing, reading, meeting, taking classes, checking out books, using computers and the Internet, printing, and so forth. The library building houses various services with areas including printers, computers, stacks, lounges, individual and group study rooms, research rooms, classrooms, presentation

and meeting rooms, a daycare, café, information desk, circulation desk, collaborative learning center, individual and group study desks, etc.

After the initial prototype of the map was created using Adobe InDesign and published as a flash file, it was uploaded on a test administrator's website for participant accesses. The map was available on a mobile device (Nexus 10) which had a  $2560 \times 1600$  (300 dpi) display, WQXGA True RGB Real Stripe PLS, and Corning Gorilla Glass 2. It had Dual-core A15 CPU and Quad-core Mali TS04 GPU. It was connected to Wi-Fi 802.11 b/g/n (MIMO + HT 40) for the map display on the website. The initial map prototype was tested by twelve people for usability. The results from the usability test were reflected in the map design update for the main test. The major feedback from the test was 1) text to encourage users to click different areas for a popup box with a detailed description of the area and an image were moved to the box area for better visibility, 2) consistency in color and text size, and 3) faster popup box appearance animation.



Fig. 1. The interactive library map sample.

The updated map was used for the main test. See Fig. 1. The map included navigation buttons with floor numbers at the top. When a user touched a certain floor button, the map displayed that floor's map. The map incorporated the university's branding color palette. Several different colors were used throughout the map. A popup box on the right was available, and text that encouraged participants to touch different areas was also included in the box. When a user touched an area, other areas' colors turned grey to make the clicked area stand out, and a popup box with a description about the area and its services and an image of the area appeared.

Four wayfinding tasks were designed. Each participant wore the mobile eyetracking glasses. The SMI Eye Tracking Glasses 2.0 was used for the study. It has an eye tracking sampling rate of 60 Hz and a recording unit connected to it which was also portable. The HD scene camera ran 30 Hz. The glasses weighed 68g with size, 173 x 58 x 156 mm. Its

gaze position accuracy was 0.5 degree over all distances, parallax compensation. Its gaze range was 80 degrees horizontally and 60 degrees vertically. The participants who regularly wore eyeglasses were excluded from the study as eyetracking glasses cannot function properly with eyeglasses. See Fig. 2.



Fig. 2. The mobile eyetracking system.

### C. Procedure

The test was conducted in the library, where a participant met the test administrator. Upon arrival, the test administrator led the participant to the research room in the first floor, where the initial demographic survey and Information Technology Literacy Test (ITLT) were conducted. ITLT required a participant to perform basic tasks in order to find a location on an interactive map.

The circle-pointing test was used to measure how well participants can estimate directions to landmark locations in relation to their own location (Hund & Nazarczuk, 2009). This test was to measure the Sense of Direction (SOD) of participants. Participants were asked to record their direction estimations of landmarks on two sheets of paper. A sheet of paper contained a blank circle and a point with an arrow in the center of the circle. The point represented the participant's location, and the arrow indicated the direction that the participant was facing. The participant recorded the direction estimation of landmarks by drawing dots on the circumference of the circle. There were three dots representing three landmarks in the building (i.e., restroom, stair, and the main entry door of the building) listed on the first sheet. The second sheet of paper listed three dots representing three landmarks on campus (i.e., Memorial Union building, football stadium, and the main administration building). After the test, a transparent angular coordinate system with 10 degree unit lines in all directions was superimposed on each sheet. The difference in degrees between the correct landmark position and the estimated landmark position was computed to measure angular error.

The duration time of the task was measured and transcribed on the survey tool. The eye tracking calibration was conducted using three-point calibration on the laptop and also using the mobile recording unit. Each participant was

required to perform four predetermined way finding tasks. The tasks were designed to seek diversity in experiments, and to observe different wayfinding behavior.

Prior to each wayfinding task, the test administrator informed a participant of the task requirements by saying each instruction sentence one by one. The instruction included five requirements, “1) look at the map and locate yourself on the map by pointing your location on the map with your finger, 2) find xxxx (room # xxxx) on the xth floor on the map, 3) plan your route on the map using elevator #x, and 4) draw the route with your finger as you say the route out loud., and 5) say “go” when you start, and say “stop” when you are done with wayfinding.” Wayfinding task 1 was from the research room on the first floor to the daycare room on the third floor. Task 2 was from the daycare on the third floor to a book stack on the fourth floor. Task 3 was from the book stack to a special collection room on the fifth floor. Task 4 was from the special collection room to the research room on the first floor. When a task was completed, a participant started the next task at the location that the prior task was completed. The eyetracking system that each participant was wearing recorded views that the participant was looking at while performing wayfinding tasks. A participant was allowed to carry the mobile device that displayed the interactive map and use it whenever the participant wanted to.

D. Analysis

The data recorded to the mobile recoding unit was transferred to the SMI Begaze eye tracking analysis software for data analysis. The software extracts data files, creates video views, and allows different analysis possible. See Fig. 3.



Fig. 3. The eyetracking data analysis program screen capture.

Using the analysis program, the route planning time, task completion time, number of errors, number of hesitations, and hesitation time were measured for each participant for all tasks. When a participant made a wrong turn and proceeded in the wrong direction, it was counted as an error. In addition, when a participant used a route that was different from his

(her) planning, it was also counted as an error.

When a participant stopped walking and planned their route again using the mobile device, it constituted of hesitation. The task completion time was measured from when a participant started wayfinding by saying “go” to when the participant stopped wayfinding by saying “stop.” Each wayfinding task involved elevator use. The duration of the elevator waiting time was subtracted from the task completion time. Depending on time of the day, the duration varied significantly. The average and standard deviations were calculated for the duration time of each activity.

For qualitative analysis, each gaze video was coded and analyzed to examine the interactive map use, hesitation point, error in wayfinding. Possible reasons for error and hesitation were analyzed.

IV. RESULTS

The average and standard deviations were calculated for time duration measurements. See Table I. Participant #4 and #8 (both female) took the longest route planning time. One was a faculty member and the other was a graduate student, while all of the other participants were graduate students. Participant #4 and 8 were the oldest two among the participants. They took the longest duration’s time for the ITLT test as well. They also showed the highest deviations at the SOD test for indoor locations.

TABLE I: THE AVERAGE DURATION

Channels	Task 1	Task 2	Task 3	Task 4
Rt. Planning	2:44 (1:35)	2:14 (0:54)	0:56 (0:12)	2:41 (0:47)
Task Completion	1:44 (0:52)	1:26 (0:13)	1:45 (0:42)	1:17 (0:32)

Unit – Min:Sec (SD)

They are the two out of eight total participants who failed to locate themselves on the interactive map prior to the wayfinding test.

Participant #2 was the individual who took the third longest task completion time and route planning time, following #4 and #8. She was successful in all other tasks but the second one. The second task taking longer was because she took fairly long time hesitating during the second task session.

TABLE II: WAYFINDING PER PARTICIPANTS

Part. #	Task Av.	Rt. Pl. Av.	Error Sum	Hesit. Sum	Hesit. Av
1	1:27	1:11	1	1	0:13
2	1:46	1:57	2	3	1:06
3	1:40	1:21	2	2	0:02
4	2:13	2:12	2	8	0:52
5	1:03	1:39	0	1	0:02
6	1:12	0:49	0	0	0:00
7	1:15	1:19	0	0	0:00
8	1:48	2:49	3	5	1:02

Unit – min:sec, numerals for frequency

Overall, participants did not make many errors. However, the frequency and the time duration of hesitation showed relations to task completion time. See Table II.

Each participant's gaze videos for the tasks were also analyzed to examine wayfinding tasks qualitatively. Some participants did very detailed route planning compared to others. It is interesting to note that participants who did rough route planning with minimal details tended to make more errors and take a longer hesitation time. However, participants who did detailed planning did not always perform successful wayfinding. In other words, even though they planned the route in detail, they still made errors or hesitated on the way.

Another important thing to note is that there was a set of elevators that was near the destination of #1 (the starting point of #2). However, the elevators were not accessible to the public. The map showed it in grey, just as other areas that were not accessible to the public. Thus, participants were supposed to use other elevators that were farther away. Only half of the participants found out that the elevators near the location were not accessible by touching the elevator for the detailed information and description.

The gaze videos were analyzed for detailed data coding for qualitative analysis. See Fig. 4 for an example. As the wayfinding tasks were conducted from Floor 1 to 3, 3 to 4, 4 to 5, and 5 to 1, maps for Floor 1, 3, 4, and 5 were created to show participants' paths. Map consultation points, hesitation points, and error behavior were analyzed using paths coded on the map.



Blue square: map consultation  
Red dot: hesitation

Fig. 4. Coded wayfinding performances example: Floor 5.

Participants consulted the interactive map on the mobile device constantly while they were walking. It happened more often at the point where the path branched to an aisle or corridor that intersected. Hesitation happened at the major decision points. One of the longest hesitations happened on the third floor where the short cut is through an aisle. However, many participants hesitated and chose a corridor to reach to the destination. The aisle was open to public but as it looked somewhat enclosed, participants hesitated even

though it was part of what they had planned. Another hesitation point was where there was another branching corridor before the destination corridor. Participants were not sure if it was the right turn to make or not.

Participants sometimes took a route that was different from what they have planned. It happened most often on the third floor, as mentioned earlier. The shortcut was an aisle that looked not very open, which made participants choose a different route with a wider corridor that looked more.

## V. DISCUSSION

This study offers interesting and practical insights to the field of interactive map design and use. Results from participant profile analysis in relation to wayfinding performance showed that three participants that experienced the most difficulties were all women, those not highly literate with information technology, and those with low indoor sense of direction. Although it may not be generalizable with this small number of participants, it showed some aforementioned trends. Thus, it will be useful to consider those populations who are not familiar with mobile device use. The design of the map should address the issue and focus on the usability of its design.

There were several areas to improve for the map design. First, the areas that are not accessible to public should have more explicit visual communication. For example, the elevators that are not accessible to the public should be crossed out to convey the message. The implicit design with grey color did not communicate the idea effectively.

Signs that are properly located will help wayfinding as well. When areas are open to public but look exclusive to certain people, signs may be needed to clarify. For rooms that are located further back and hidden, signs protruding from the wall may help.

For future research, a study with a bigger sample size will be helpful to provide more evidence for the results that this study provided.

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