Using a Mobile Application to Help Visually Impaired Individuals Explore the Outdoors

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Abstract. Visually impaired individuals face a variety of challenges when navigating outdoors, including uneven terrain, unexpected obstacles, safety concerns, and reliance on others for information. The goal of this study was to understand further the navigational needs of visually impaired individuals and to develop a mid-fidelity prototype to address these needs. Through interviews with visually impaired users and accessibility professionals, researchers found that present technology leads to an incomplete understanding of the trail and harmful situations. Currently, there is no known technology available that integrates real-time updates with static trail information for individuals navigating outdoors. In response, a mobile prototype was proposed, integrating user-provided updates with static trail information in a format that caters to all users. Our usability testing showed visually impaired users made few errors using the prototype and were satisfied with their experience.

Keywords: Wayfinding · Visual Impairment · Assistive Technology

1 Introduction

According to the World Health Organization, 285 million individuals suffer from visual impairment [1]. This term describes a range of ability from blindness to low vision, defined as visual acuity of not greater than 20/200 to 20/70 with correction [2]. Although four percent of the world's population is visually impaired they still encounter many barriers to living an active lifestyle. In particular, it is hard to navigate new and unpredictable environments. For instance, hiking presents too many obstacles for most visually impaired to safety attempt.

When hiking, sighted individuals rely heavily on visual cues to successful move through unpredictable environments. Seeing obstacles, such as downed trees or uneven terrain, allows sighted individuals to avoid the hazard and plan an alternative route. Visual signs and landmarks help the sighted navigate successfully. Public nature trails were developed with the expectation that hikers have normal vision. Those who are visually impaired and motivated to hike. Must complete extensive planning like creating and reviewing a tactile map. During the hike, they must carefully use a white cane to identify hazards. However, they are still unable to access crucial visual cues to facilitate safe and comfortable hiking. Clearly, disabilities arise from the inaccessibility of crucial cues needed for successful interactions between users and their environments. If visually impaired individuals could access crucial cues at this right moment, they could enjoy the benefits of hiking. We suggest that technology may provide the visually impaired with access to crucial cues through auditory and tactile modalities. However, we still need to understand further their hiking needs to provide human-centered design recommendations [3].

1.1 Current Navigational Strategies and Technologies

Design Principles. Hersh and Johnson [4] defined design principles for visually impaired individuals' independent travel. The authors asserted that an assistive technology should be easy-to-use and cost-effective. Also, the technology should provide more information than widely-used solutions, such as the white cane. For example, assistive technology should aid in avoiding obstacles, minimizing hazards, and understanding orientation information, such as signs.

Currently, many visually impaired individuals use a white cane or a dog guide to aid in autonomous navigation and travel [5]. Both of these methods are limited when used outdoors. Although the white cane is effective in many developed environments, it cannot always guarantee safety to the user, as obstacles such as potholes or debris may block the user's pathway unknowingly [6]. Guide dogs offer a viable alternative, but many training organizations limit use in hazardous situations, such as hiking independently [7]. Considering these limitations, many researchers have implemented solutions.

Current Technology Advantages and Disadvantages. One approach used to aid navigation is accessing tactile and embossed maps. Before a trip, visually impaired individuals use the map to gain information about elevation changes and the location of major landmarks. With the advent of 3D printers, printing maps with tactile feedback has become easier, though these maps still have drawbacks. When tactile labels are also used on the map, legibility of these maps decrease [8]. Further, tactile and embossed maps only reflect static information about the trail. Also, their size makes them unpractical to carry on the trail. Götzelmann [9] developed an approach which allows a smartphone to scan a tactile map and identify labels via barcode. Exploring the tactile map with one hand and reading the labels with the other is possible. Plus, Hamid and Edwards [10] added an egocentric rotation component to help with cognitive mapping. The prototype was implemented on a Talking Tactile Tablet. These studies are helpful for planning a hike but are not a solution for active hiking.

Recently, some researchers used newer technology, including ultrasonic, infrared, camera, global positioning system (GPS), and sonar to develop an electronic stick [6, 11, 12, 13]. These devices scanned the environment for obstacles and communication information about the environment using tactile feedback. Although these systems improved navigation, the devices require extensive training. Unfortunately, electronic sticks are costly and too bulky to use on the trail [14, 15].

Mobile applications are particularly promising as an assistive technology for visually impaired individuals because of their size, cost, and feedback capabilities. Applications such as Google Maps, The Seeing Eye GPS, and Navatar address some of the current limitations. These applications rely on auditory feedback to help the user determine their present and future locations. Navigation information from these applications is limited to boundaries previously established by aerial mapping and do not assist off-road navigation. Hiking-specific applications, such as Trail Tracker or AllTrails, function primarily as a recording device to track performance and only provide static information about the trail. Interestingly, these hiking navigational applications for sighted individuals are also lacking. Current applications provide little to no real-time information and are only available along roads or sidewalks. If sighted individuals had access to real-time information, they could plan their hikes around poor trail conditions or improve the conditions of the trail (e.g., moving downed trees). The proposed mobile application would benefit both sighted and visually impaired populations.

1.2 Benefits of Increased Mobility

Adults with visual impairment report poorer or declining health in comparison to sighted adults [16]. Similar trends have been found when comparing visually impaired and sighted children [17]. This disparity is caused in part by less physical activity in the visually impaired population. Real and perceived barriers to exercise, including barriers to walking alone outdoors, may be to blame [18]. By creating a navigational mobile technology, the activity level of visually impaired individuals may be greatly increased.

Exploring the outdoors provides many potential health benefits. In addition to improved health, increased mobility can lead to improved physical activity, which improves the quality of life for all individuals. Walking independently increases overall feelings of independence for visually impaired people [4].

1.3 Purpose

The goal of this study was to understand further the navigational needs of visually impaired individuals and to develop technology to address these needs. Existing technology is limited and does not encourage the visually impaired to explore the outdoors. Ideally, this application will equip visually impaired individuals with the crucial cues to navigate more effectively outdoors.

2 Design Overview

2.1 Interviews

To further understand how visually impaired individuals navigate outdoors, the researchers conducted a series of interviews with subject-matter experts and potential users. Subject-matter experts included an avid distance blind hiker and three accessibility professionals (e.g., Orientation and Mobility Specialist). Five visually impaired participants (3 Turkish, 2 American) were also interviewed. Researchers developed a semi-structured interview script with questions regarding levels of visual impairment (or the degree of visual impairment of a typical client), typical strategies, and navigation experiences. Additionally, participants were asked about current technologies and the qualities he or she would like to see in a potential navigation tool.

Researchers found that lack of map accuracy, lack of accessibility, and lack of compatibility with certain phones frustrated users. According to these participants, their frustration often superseded the benefit of the technology; many opted to forego newer technology. Instead, they relied on white canes and pathway memorization exclusively. Given the required effort for travel and fear of falling on the trail, they rarely traveled outdoors for recreation. When they did travel outdoors, they dependent on nearby pedestrians due to the poor performance of navigation technology. Additionally, participants mentioned having difficulty quickly identifying the battery life on their device and were concerned about their phone dying on the trail. This information confirmed barriers and needs found in the literature. Because all participants possessed a cellular phone and attempted to use it at least once for navigational purposes, we then asked participants about a potential need for a new navigation tool. Users expressed a need for a map function with auditory feedback and obstacle warnings.

2.2 Storyboard and Sketching

After evaluating interview data, storyboarding began. Researchers created storyboards for situations that might occur when using a navigational mobile application. These storyboards were presented to two potentials users. One potential user suggested adding locations of interest to the map, such as shelters and trail markers. The potential users also reemphasized the importance of safety. From this, researchers added a quick way to call emergency services.

2.3 Personas and Scenarios

From the literature review, interviews, and sketches, researchers developed three personas and scenarios to help contextualize user needs (Table 1).

Table 1. Personas and scenarios of potential users.

Name	Personas	Scenarios
Juin-Huei	• 43-year-old male • Blind since birth • Lives within walking distance of work • Spends little time outside recreationally for fear of getting lost	• Typical route to work is blocked by construction • Uses white cane but cannot navigate around the construction • Can walk through the park but chooses not to because unfamiliarity

Melek	• 24-year-old female • Low vision due to disease since age 20 • Former cross-country athlete • Rides the bus but the system is often busy and unreliable • Occasionally goes outside for recreation	• Decides to walk a familiar path that she knows from when she ran cross country • Uses a white cane and her memory to navigate • Twists her ankle on the trail due to downed tree and needs help walking home
Barbara	• 67-year-old female • Low vision due to cataract • Lives in mountains and enjoys hiking • Attempts to use tactile maps and mobile applications to aid hikes	• Hikes alone but prefers a partner • Navigates using a hiking pole and a mobile application • Finds mobile application frustrating and inaccurate • Rain begins halfway through hike

2.4 Design and Usability Goals

We needed to provide a portable map for users to access while anywhere. Portability was an emphasized need our interviewees reported and our literature review revealed. This map should allow users to tag obstacles in an outdoor setting like downed trees, mud, possible wild animals, and holes. Plus, obstacles in an urban setting like downed trees and construction (see, Jiun-Huei). Another important feature was a way to check the weather updates and phone status (like in Barbara's scenario). The design should enable users to share their experiences and connect with other hikers. Also, as emphasized by our interview findings, a quick way to contact emergency services is essential to feel confident hiking alone.

Regarding usability goals, the mobile application should have an interface that is easily accessible to a range of users as barrier exist for all levels of visual impairment. It should also enable current technologies (e.g., VoiceOver) to be easily integrated into the design, a frustration our users commonly reported about current solutions.

2.5 Tasks

A mid-fidelity prototype was created using Axure software. Auditory feedback for each screen option was provided by activating Apple's accessibility settings and VoiceOver.

Task 1 required participants to check the battery life of the device. The user was expected to select the Phone button and read the battery life information (Figure 1). Task 2 asked participants to imagine falling and needing to call emergency services for help. The user was expected to select the Emergency button and Emergency Services (Figure 2). Task 3 required the selection of a recent trail (i.e., the Osmanthus Trail). They were expected to select Route, Recent, Osmanthus Trail, and identify trail information (Figure 3). Task 4 involved reporting a downed tree. The user was expected to select Social, Report, record the trail condition, and review on the map (Figure 4).

Fig. 1. Sequence of events for Task 1. Users select the bottom button to begin, select Phone, and then access information about battery life using a screen reading software (e.g., VoiceOver).

Fig. 2. Sequence of events for Task 2. Users select the bottom button to begin, select the emergency button, then select Emergency Services (e.g., 911 in the United States).

Fig. 3. Sequence of events for Task 3. Users select the bottom button to begin, select Route, and then select Recent. Next, they select Osmanthus Trail and access important trail information, such as shelters, water, or user-tagged hazards.

Fig. 4. Sequence of events for Task 4. Users select Social, Report, record the trail condition by holding the button and speaking, and review on the map

2.6 Use Cases

To understand the usefulness of this application, researchers developed use cases for each of the personas. In the scenario about Jiun-Huei, he encounters construction on his typical route and needs to find an alternative route. Using the application, Jiun-Huei would open the mobile application, identify the alternative route through the park through Recent or Nearby Trail, and select the route. After selecting the route, he could touch the pathway to learn about elevation changes through tactile feedback and major landmarks and user-tagged obstacles through auditory feedback.

When Melek encountered a downed tree, she could have tagged the obstacle by selecting the Report function, which recorded the trail condition for future users. She could also quickly call Emergency Services from the home screen.

Barbara would be able to identify dangerous weather before it began storming using the Weather button on the home screen. She could then seek shelter immediately as instructed.

3 Design Overview

The goal of our usability testing was to determine whether the created prototype was easily accessible to a range of visually-impaired users. Here, the most important usability dimensions were errors per task, efficiency, satisfaction of application, and clarity of design. These dimensions were measured time on task, errors on task, and perceived satisfaction.

3.1 Method

Six participants (M = 37.75, SD = 28.86) from two different countries (2 Turkish, 4 American) tested a mid-fidelity prototype of a mobile navigation application. Participants ranged in visual impaired from low vision to total blindness. They were recruited by public flyer and entered to win a $50 Amazon gift card as compensation.

All participants completed a demographic and a navigation-related questionnaire before beginning. Next, participants were asked to imagine navigating outdoors. During usability testing, the four tasks previously mentioned were complete using the mid-fidelity prototype. Upon completion of the fourth task, the System Usability Scale (SUS) was administered, and participants answered a post-task questionnaire [19].

3.2 Results

Usability dimensions for testing the prototype, including errors per task, efficiency, satisfaction of application, and clarity of design to receive constructive feedback for improving the mobile application. Participants completed all tasks in under one minute (*M* = 27.82, *SD* = 9.47). Minimal errors were made in the first three tasks (Figure 5). An error was made when participants clicked the wrong button on the screen or had to ask for help. Any number of errors could be made during each task. Due to most errors being made in the fourth task, changes were made to the initial prototype. Interestingly, scores on the SUS signified high satisfaction with the application (*M* = 88.33, *SD* = 9.04), revealing positive feedback towards the proposed navigational mobile application.

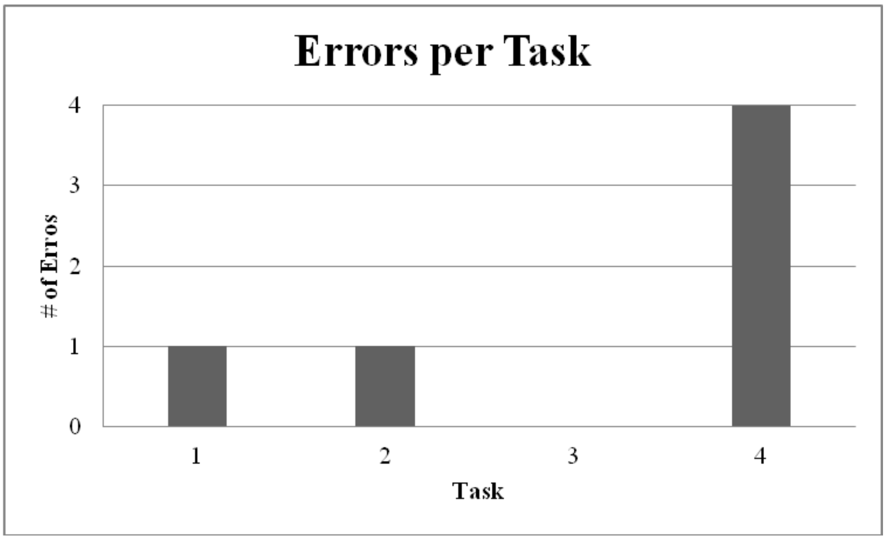

Fig. 5. Number of total errors per task. Task 3 contained no errors.

3.1 Discussion

Independent navigation outdoors is a problem for a range of visually impaired people, from low vision to fully blind. A lack of physical activity in this population may be a detriment to overall health and feelings of independence. Based on information gathered from previous research, subject-matter experts, and potential users, there are many barriers to walking independently outdoors, including fear for safety and frustration with current technology. In particularly, current technologies are either unreliable or are not compatible with uneven terrain encountered outdoors. Users desire a reliable way to access information about weather, obstacles, and emergencies on their phone. Through an iterative human-centered design process, we created a mobile application prototype with auditory and tactile feedback. This prototype includes a way for users to tag obstacles to notify future users who may encounter the same obstacle in their path. It also includes a quick way to call emergency services for help, as well as gather information about the weather or phone status quickly. Currently, no technology like this exists on the market for visually impaired or sighted people.

In the future, researchers should continue investigating how to communicate best visual cues to visually impaired people. New technologies like Tactus make gaining this understanding now particularly important. Finding how to communicate best cues that sighted people identify visually is essential to bridging the current accessibility gap. Additionally, most novel technologies developed by researchers have not been testing in the field, particularly on uneven terrain. Researchers need to test navigational tools in both laboratory and field settings.

By providing an easy to use interface with constantly-updated trail condition and obstacle information, visually impaired people and sighted people will be able to navigate more effectively uneven terrain. This opportunity allows visually impaired people to exercise more. This increased exercise can lead to improved health, independence, and overall quality of life. By giving them access to visual cues through tactile and auditory feedback, individuals can spend less time worried about hazards and more time enjoying the outdoors.

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