In-Place Virtual Exploration Using a Virtual Cane: An Initial Study

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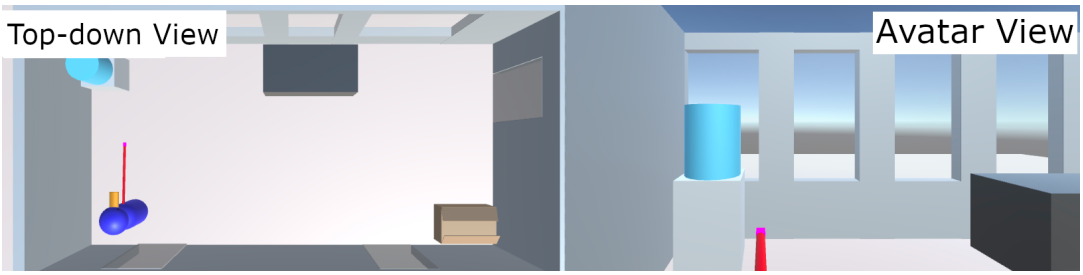

Figure 1: Image of the application in use.

ABSTRACT

In this initial study, we addressed the challenge of assisting individuals who are blind or have low vision (BLV) in familiarizing themselves with new environments. Navigating unfamiliar areas presents numerous challenges for BLV individuals. We sought to explore the potential of Virtual Reality (VR) technology to replicate real-world settings, thereby allowing users to virtually experience these spaces at their convenience, often from the comfort of their homes. As part of our preliminary investigation, we designed an interface tailored to facilitate movement for BLV users without needing physical mobility. Our study involved six blind participants. Early findings revealed that participants encountered difficulties adapting to the interface. Post-experiment interviews illuminated the reasons for these challenges, including issues with interface usage, the complexity of managing multiple interface elements, and the disparity between physical movement and interface use. Given the early stage of this research, these findings provide valuable insights for refining the approach and improving the interface in future iterations.

CCS CONCEPTS

• **Human-centered computing → Accessibility design and evaluation methods**; **User studies**.

KEYWORDS

Mobile Virtual Reality, Visual Impairment, Spatial Learning

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1 INTRODUCTION

When entering a new room, we use our eyes to look around. We are able to figure out what is in the room and where those objects are without having to walk through it. This is difficult for people who are blind or have low vision (BLV), since they have to rely on their cane to touch objects in order to visualize the room. BLV people often request orientation and mobility (OM) training when they need to access a new environment frequently. However, OM training is very time-consuming, and they must make an appointment with an OM instructor a few weeks in advance. To address this issue, a virtual cane has been proposed [6, 12] to provide a VR simulation to assist BLV people in exploring a virtual space. It allows them to explore a real-world space in a virtual environment for as long as they desire. However, the virtual cane design often requires a 1-to-1 ratio of space between the virtual and real-world environments, making it challenging to explore large virtual areas without sufficient physical space. In this initial study, we aim to overcome this challenge by expanding on the virtual cane design, focusing on exploring large virtual areas while remaining stationary.

2 RELATED WORK

This research explores how to incorporate VR into the everyday lives of BLV individuals. Teaching with VR is not a new concept, and many researchers have been working to make it a more effective form of learning. Even schools have investigated the use of VR to enable their students to explore distant places that these students might otherwise never have had the opportunity to learn about [4].

2.1 Spatial Awareness

Spatial awareness is crucial because if users do not understand their orientation relative to the world, they can't grasp the positions of their environment and the objects within it. Orientation and

Mobility (O&M) training teaches blind users to be more aware of their position and rotation to prevent them from getting lost in their surroundings[1]. Many navigation-based applications achieve this by tracking the phone's geographic location and guiding users accordingly [3] [10]. Others, more uniquely, inform users about local points of interest (POI) [1], hoping that this knowledge will help them navigate the real-world counterpart more effectively.

2.2 Haptic And Auditory Feedback

Non-visual feedback from the app is very important as it provides users with information. This is essential for BLV users since it's one of the few methods through which the phone or device can communicate with them. The most common form of feedback is auditory feedback, which can provide directions or information about the environment. The other form is the haptic feedback. Another type of feedback is haptic feedback. Haptic feedback can convey various messages: guiding users to a specific object [8], indicating where and when to perform certain actions [9], or serving as a response to interactions with virtual objects [7].

2.3 VR Interface

How BLV users interact with their virtual environment can determine the enjoyment level of your application. Many games use a controller or a keyboard to control their virtual avatar [5]. A more creative approach uses a modified cane; when BLV users encounter a virtual object, the cane artificially creates resistance, simulating the sensation of hitting a real object [6, 12]. A simplified yet accessible solution is proposed by [11], and it develops a virtual cane on an iPhone. To reduce the space limitation, a treadmill is used to allow BLV users to walk and interact with the virtual environment as though they are in it [2]. Others take a more straightforward approach and use the phone's gyroscope to control movement [1].

3 METHODOLOGY

3.1 Overview of the system

In this initial study, we build upon our earlier work on the Mixed Reality (MR) Cane[11], a system that creates a virtual cane on an iPhone. We do not include a selfie stick in this study. The design is entirely accessible to BLV users, as they only need their iPhones and earphones to explore a virtual space with the MR cane. The iPhone acts as a virtual cane and it produces users with both auditory and vibration feedback when it interacts with a virtual object. In the design concept of the MR Cane, one can envision the virtual cane extending from the iPhone's camera. In this research context, the iPhone functions as the handle of the cane, with the remaining part of the cane extending from the top of the device.

3.2 User Controls

Like other accessible mobile apps, there must be a way for BLV users to control their avatars. For this purpose, we utilized Unity's AR Foundation, which enables us to monitor the position and rotation of the iPhone and translate this data to the avatar. The cane moves with the iPhone. If users want to move, they have two options. Swiping up or down on the iPhone screen causes the avatar to move up or down, respectively. The avatar will continue in that direction if the user keeps their thumb on the screen. When they lift their thumb, the avatar stops moving. To prevent confusion regarding the avatar's movement, it is designed to move in only one direction at a time and cannot turn until the user lifts their thumb. Another feature is the "Rotation Info". By tapping the phone screen, users receive audio feedback through the earphones, indicating their direction based on clock degrees. This provides a frame of reference if they feel disoriented. There's also a bump feature that nudges the avatar back when it collides with an object.

Participants can maneuver their phone as if they're wielding a cane. When the cane encounters a virtual object, the phone vibrates, and a tapping sound emits from the virtual object via the earphones.

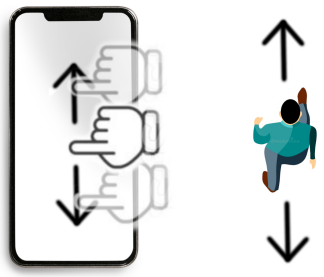

Figure 2: Controls of the In-Place mobile app

3.3 Auditory Feedback

Several features have already been implemented in the app. Many of these provide auditory feedback to the user when their cane interacts with an object. Beyond this, there are a few new features designed to further assist BLV users. One such feature is activated when the user swipes on their phone; it triggers two audio cues: one indicating the direction they are walking in, and the other simulating footsteps for the duration of their walk. Another feature is the 'Bump' function. If the avatar collides with an object, the user will hear a bump sound followed by a voice notification indicating the collision. Additionally, the avatar will recoil slightly, preventing it from becoming stuck.

3.4 Approach to development

There are several approaches to in-place movement. The most feasible one involves creating controls that are simple to understand and use. We were concerned that relying solely on the phone for control might hinder users from forming a mental map. Thus, we wanted users to physically turn themselves to pivot their avatars. We also modified the way users hold their phones. The original MR Cane design utilized a selfie stick to emulate a cane's function, whereas in this research, the phone itself imitates the cane. This change provides us access to the touchscreen, offering more control possibilities.

[1]https://www.nationaldb.org/info-center/educational-practices/orientation-and-mobility/

4 USER STUDY

4.1 Participants

Six participants were invited to conduct the user study. Their blindness level varies from light perception to total blindness. Their age varies from 23 to 72. They all experience some form of O&M training, though some have more experience from either age or taking more lessons. All but one person are currently using a cane, and one person is using a guide dog. They all have experience traveling indoors and outdoors alone. They all use phones and some apps to help guide/navigate them in their everyday life. None of them have experienced VR, though some of them have heard the concept.

4.2 Virtual Environment

The virtual environment shown in *Figure 3* is a simple room about 10 meters long and 5 meters wide with three pieces of furniture. The avatar starts at the southwest of the room facing 12 0' clock. The three pieces of furniture are the water dispenser on the northwest, the cardboard box on the northeast, and the metal table on the south. There are three doors, two on the south wall and 1 on the east.

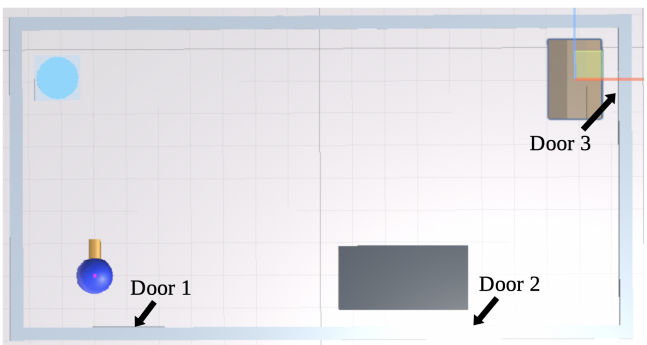

Figure 3: Overhead view of the Map

4.3 Set Up

We first asked the participants various questions to understand their experience. These questions are listed below. We also tested their mental map ability by giving them a small room (1 foot x 1 foot) made of Lego blocks, at the center is a Lego piece that represents the participant, and various Lego pieces scattered around representing furniture or different shapes and sizes. We allowed them one minute to feel around the room. Afterward, we removed the furniture and asked them to recreate the room. After the questions and Lego test, participants are given two devices: an iPhone and AirPods. We elaborated on the objective of this experiment, which aimed to assess the feasibility of exploring an area without physical movement. They started in a simple virtual environment that acted as a tutorial level. We first warmed them up to holding an iPhone and explained to them how the phone can be used like a cane. After we introduced the controls and features while letting them test it, we explained the various feedback they could expect and helped them experience it. Lastly, we gave them a small task of moving around a wall to find furniture. Once they were as comfortable with the controls as they could get, we moved on to the experiment. In the experiment room *Figure 3*, the participants had ten minutes to explore. We addressed any questions or concerns they raised during this exploration phase. Upon completion of the experiment, we asked them two questions for assessment based on their answers.

- What is your level of Blindness?
- When did you become interested in working with us?
- Is your blindness "innate" or "post-natal"? If post-natal, how many years have you been blind?
- Have you received any O&M training?
- Do you know how to use an iPhone?
- Do you know how to use the touchscreen?
- Do you know how to "swipe" on the touchscreen?
- Are you familiar with the concept of Virtual Reality?
- Have you ever used AirPods?
- Have you played or are familiar with digital games where you use a control to move things?
- Are you able to accurately identify right and left?
- Are you able to identify "clock positions"?
- Are you able to accurately identify the direction of sound in the real world?

4.4 Assessment

We asked only two questions: whether they found a particular object and where the object was located. For identifying objects, we either asked them to list all the objects they found, or just went down a list and asked if they encountered a specific object. Regarding the object's location, we were lenient with their answers since we only wanted to test their general understanding of the map. So long as they pointed the general direction where the object is located, we considered it correct.

5 RESULTS AND ANALYSIS

In *Figure 4*, the participants' results are displayed. They were able to identify most of the objects in the room. The left bar indicates a median of 2.5, signifying that participants typically found either 2 or 3 objects. However, most participants struggled to pinpoint their exact locations. The right bar displays a median of 0.5, suggesting that most participants correctly located either 1 object or none at all. These findings underscore that while participants could identify many of the objects, they often couldn't determine their precise locations.

6 DISCUSSIONS

Overall, the controls of In-Place exploration using the proposed approach still need further improvement. While the results show some promise, the room wasn't very challenging, yet the participants struggled a lot. What was enlightening was the feedback provided by the participants. In *Figure 5*, the second box plot illustrates the comfort level of app usage, receiving the lowest overall rating. While observing the participants using the controls, many participants had trouble moving the cane while swiping up or down. This could be due to misunderstanding the instructions, insufficient practice time with the controls, or an inability to comprehend the

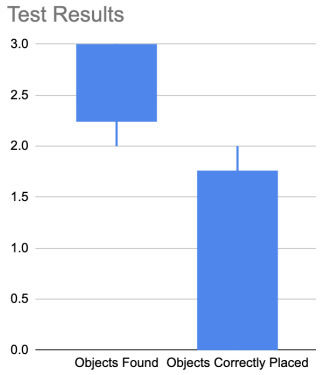

Figure 4: Participants' Result

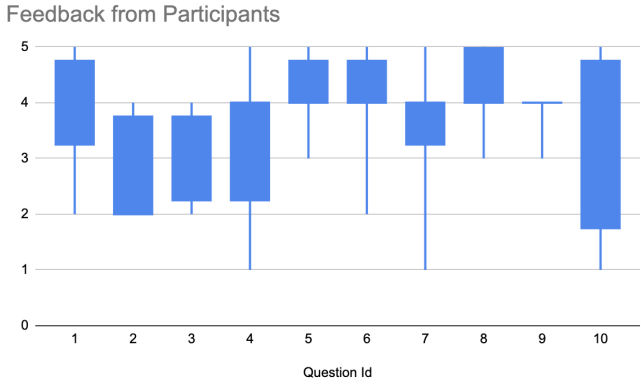

Figure 5: User experiences. Questions from left to right: 1. How comfortable is holding the phone? 2. How comfortable is it to use this app? 3. How easy was it to move? 4. Do you think this will be helping in learning the general layout/creating a mental map of new areas? 5. How useful was the training? 6. How useful is the Rotation Info? 7. Do you see this being useful to explore new places? 8. How useful is the Bump feature? 9. Did they ever feel lost (more than usual when exploring new areas)? 10. Did they feel like they were in an actual room?

concept. The third box plot measures the ease of movement, and it had the second lowest grade. Beyond the challenge of using the cane while moving, most participants struggled to move using their thumbs and instead had to turn with their bodies. Some participants even started to swipe on their phones to turn their avatars. The combination of incorporating both movement and hand gestures to control the avatar led to confusion among several participants. We also asked some participants about some aspects of the app, such as their general troubles. A consistent challenge was the sensation of movement. Since participants moved the avatar using their thumbs, they lacked a tangible sense of how far the avatar had traveled. And because they cannot feel the distance traveled, it made it harder to build a mental map. This combination of frustrating controls and lack of awareness in distance traveled, left the participants feeling lost and confused for the most part. For future design considerations, we could potentially introduce additional methods for users to gather information about their surroundings. This might include features that provide their current location, the distance they've traveled, objects in close proximity, or any other elements that would offer them a sense of the distance they've "walked".

7 CONCLUSION

The concept of In-Place exploration is to allow users to explore any area without space limitations. The original design aimed to virtualize how BLV users interact with their environment, but it required an equivalent physical space for virtual exploration. The proposed interface aims to overcome this limitation by enabling BLV users to navigate their avatars without physically movement. The user study showed that many BLV users found it challenging to use the interface to navigate in a virtual space, though the interface is simple. Other challenges, such as not feeling a sense of movement, made it hard for some participants to discern their location within the room. Overall, the current controls and feedback mechanisms are insufficient for users to construct a mental map of an area. Nevertheless, many participants recognized the potential utility of the concept, and further progress is encouraged. After all, as many of us can experience the world through our phones, we aim to offer the same opportunity to those with visual impairments.

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