Journal of Human Centered Technology Vol. 2: No. 1 (2023) 1 – 10
Journal of Human Centered Technology
E-ISSN: 2821-3467
https://humentech.utm.my

Improving Navigation for Blind People in the Developing Countries: A UI/UX Perspective

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Received 22 September 2022; Accepted 28 October 2022; Available online 06 February 2023
https://10.11113/humentech.v2n1.31

Abstract:
Assistive technology (AT) has made many tasks possible for people with disabilities. Unfortunately, almost no technology is developed centered around the blind people of developing countries when it comes to navigating. This study explored blind people's concerns and determined the type of design and interaction of a navigation application that are more convenient and favored by blind users. Qualitative research was used to study the problems faced by blind people of developing countries while navigating. Blind people of two organizations in Bangladesh participated voluntarily in the research. The data obtained were analyzed using thematic analysis of ATLAS.ti. The data indicated that merely traveling with the white cane was not enough and there were a lot of problems faced when going from one place to another. A preference was shown for voice-assisted devices. The data were used to build two types of accessible prototypes with good UX, but different interactions, design, layout, spoken content and audio descriptions. Later, the usability testing was performed to investigate the effectiveness of the two types of prototypes from the UI/UX perspective. The results indicated that there was a greater preference for a layout with more spacing and buttons closer to the hands. Audio descriptions, spoken content and being able to navigate using the application also instills a sense of independence. The study contributes to a better knowledge of design solutions and interactions that legally blind people prefer, and to the creation of navigation tools/apps for the blind, specifically from the developing countries such as Bangladesh.

Keywords: Assistive technology; Disabilities; Qualitative; Legally blind; User-interface; User-experience

1. Introduction

In today's day and age, technological advancements are prevalent and everyone is aware of how technology can make a true difference in our day-to-day life. However, in developing regions, Assistive Technology (AT) may be a relatively new term. AT is a catch-all word encompassing items and services used by people with disabilities to enable and improve their involvement in all areas [1]. However, in the developing countries or low-income countries not many people are aware of AT and not many AT products are built considering their needs. Evidence suggests that around 90% of individuals who would benefit from assistive technologies do not have access to them, and that there is a significant unmet demand for such devices [2].

According to research published in The Lancet Global Health [3], there are an estimated 36 million blind individuals worldwide, with this number expected to rise to about 115 million by 2050, with the highest impact happening in emerging nations in Asia and Sub-Saharan Africa. Furthermore, according to the Daily Sun (2021), more than 750,000 persons in Bangladesh are blind, out of a population of 30 million or more, and there are around 40,000 visually handicapped women and children.

The aim of this research is to study the problems faced by legally blind people when navigating with current tools and technology, and to also discover what kind of spoken content, audio descriptions, interaction, design, and layout that are more convenient and preferred by blind people-when navigating. By working along with two blind organizations in

Bangladesh; BERDO (Blind Education and Rehabilitation Organization) and VIPS (Visually Impaired People's Society), the problems are discovered and identified, before we proceeded with the proposal of two most suitable types of accessible prototypes with good UX, but different interactions, design, layout, spoken content and audio descriptions, which address the user's problems and concerns, and lastly, we will compare and contrast how the user engages with the two prototypes that have been developed and investigate the effectiveness from a UI/UX perspective.

2. Background and Related Work

2.1 Assistive tools for the blind

People in industrialized countries were first fully dependent on others for basic requirements and travel. Following that, many blind individuals relied on the traditional white cane and trained dog to guide their way [4, 5], despite their limitations. A white cane is a gadget that assists blind individuals in evaluating their environment. Although the white cane is inexpensive, it is incapable of detecting barriers and can only detect impediments by touch, leaving the user less time to respond to situations, which is exceedingly dangerous. Sharma [6] proposed a framework called "virtual eye" that assists with working on the versatility of an outwardly tested individual in a specific region. Meanwhile, Bharambe et al. [7] developed a concept dubbed "substitute eyes for the visually handicapped," in which the established framework primarily aids in impediment identification and the APP aids in bringing exploration. Sangami et al. [8] developed a mobile stick concept to let visually impaired persons move autonomously both indoors and outside. Likewise, Ramadhan [9] proposed a wearable savvy framework to work on the autonomous and safe portability of visually impaired people.

The most common AT that is used by blind people and visually impaired people in developing countries, specifically in Bangladesh and (in this case), is only the white cane as it has been observed. The white cane is a traditional navigation tool and a mark of identity for blind people in developing countries because of its low-cost, dependability, efficiency, and simplicity, and it allows for direct physical engagement with the earth via signaling effects. There are many Assistive Technology (AT) developed particularly centering blind and visually impaired people. But, most of the ATs are designed, developed, and tested around people from developed countries. The field research is not done concerning the different aspects of developing countries, such as the noise, people, language, roads and the average income of people. Moreover, the requirements vary for legally blind people and for people with low-vision as their needs are different, especially in low-income countries. The white canes that are so commonly used by the people of developing countries are considered traditional, compared to the ATs available in western countries. It does not provide the blind user with any kinds of specific instructions when moving around. Just a white cane is not enough for a legally blind person to move around safely.

2.2 User-experience

In recent years, the UI/UX framework has gained massive attention because of its user-centric approach towards designing technology. Garrett [10] demonstrated the UX framework by splitting it into Strategy, Scope, Structure, Skeleton, and Surface by segmenting it layer by layer from the strategy of establishing the user's goal with the UX interface through cognitive and sensory qualities that drive user behavior to the surface. Recently, the design interface for UI/UX prioritizes needs first [11].

Human movement is an essential part when we use our devices or computers. Our arms, wrists, and fingers are occupied by keyboards, desks, and touch sensitive screens. Thus, aligning human mobility restrictions and capabilities with computing interaction approaches systems is a vital field of study in human computer interaction (HCI). Fitts' law is a paradigm for both prediction and measurement. Fitts' law is a prediction equation that gives the time to acquire and pick a target dependent on the distance traversed and the size of the target [12].

3. Materials and Methods

The methodology that is used in this study is the Design Thinking process. The design process is divided into five phases: empathize, define, ideate, prototype, and test. In these 5 phases, a qualitative research approach is integrated and thematic analysis is adopted in order to analyze the gathered data.

2.2.1 Phase 1: Empathize

In phase 1, the aim is to understand and study the problems that are faced by blind people while navigating. This is done by studying the current ATs used by blind people and also by conducting an interview. The interviewees are recruited by contacting two notable NGOs in Bangladesh, BERDO and VIPS (Visually Impaired People's Society), is a

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national level right based disabled people's organization. Their participation is voluntary and their informed consent is also taken regarding the recording of the interview. A total of 14 participants took part in the research. The interview conducted resembles a semi-structured interview as this offers flexibility and is not rigid in any sense. The questions that are asked are as follows:

- How do you go from one place to another?
- What problems do you face while navigating?
- How do you think the current situation can be better?

Some of the essential findings from the interview transcript are translated and given below:

Most of the participants use the white cane or the smart white cane. They also have to be dependent on other people for their location and directions. P1 quoted, "*We have the white cane for now and that is what we use. We have been taught some tricks and tips on using the white cane as well. It somewhat helps me. I try to use my audible powers and oral communication as well. I ask people for directions when going from one area to another. Like, while coming I kept asking the passengers where we were at the moment.*".

All of the participants were dissatisfied with the current modes and methods. P6 said, "*With the white cane, it doesn't really give us specific directions. However, the smart white cane does give vibrations, which helps a bit. But, the main problem is the lack of specific direction and locatio*n.". Although most participants were using or tried using the smart white cane, it was completely useless for P4. P4 quoted, "*Smart white cane is not fully suitable for our country either and it is not really useful for me at this point. I tried using it, but it didn't prove to be useful for me*."

Moreover, P3 also showed concerns about the assistive technologies being based on the developed world, and not being centered around Bangladesh. P3 quoted, "*Well-developed assistive technologies, such as Google glasses or Microsoft Soundscape, are too expensive for me. And, they are also based in developed countries, not Bangladesh*.". Undoubtedly, price was also a concern.

Almost all participants showed preference for a voice-assisted or an instruction-based software/application. P1 said, "*Maybe if something gives proper direction and tells me what is around us, it may be hopeful. Instruction-based something would be helpful*". Moreover, the majority of the participants would prefer a combination set of devices, such as an earpiece/earphone, voice-assisted application, and the smart white cane/white cane. They do not want to let go of the cane as it gives them a sense of awareness. However, most of them were keen on the voice-assisted and instruction-based application as an addition. P5 quoted, ". *Maybe a full set for blind people would be useful, an earphone, an app and a stick would be helpful*.". There were concerns about being aware of the external surroundings. Some of them would also prefer the option of receiving instructions in their native language.

2.2.2 Phase 2: Define

In this phase, thematic analysis is used to analyze the data obtained from phase 1. The qualitative data analysis tool that will be used is ATLAS.ti. The purpose of a thematic analysis is to find themes, or relevant or intriguing patterns in data, and then utilize these themes to address the problems faced by the blind users [13]. This phase helps to create a goal for the design of the product. The thematic analysis of the interview transcript is performed by generating initial codes and patterns according to the subject of the interview. The data organized by subject, code and theme from the interview transcript is given in Table 1.

2.2.3 Phase 3: Ideate

The mind-maps are developed based on the needs of the user personas and also keeping the thematic analysis in mind. It is a navigation application, which has instruction-based features. As the users cannot use their vision, they make use of other senses, such hearing, touching, and speaking. The features of the navigation application achieve all of the user persona's goals and tackles all the frustrations, except raising awareness and receiving weather updates (see Figure 2 left). The features are given according to the following codes of thematic analysis: (1) to (8) and (10) to (12). The second mind-map displays all the important UI/UX (user-interface/user-experience) aspects of the navigation application. As mentioned in the earlier chapters, UI/UX is especially important, in terms of button layouts, button response, button size, instructions per page, and button placement (Figure 2). These are the UI/UX aspects of the navigation application that will primarily be investigated in this research. It is important as users are blind.

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Table 1. Organization of data by subject, code, and theme

Subject	Code	Theme
Current mode of navigation	1. White cane 2. Smart white cane 3. Family member 4. Friend 5. Asking other people for directions and locations.	• Non-satisfactory feeling while using the current modes. • White canes and smart whites are the most common. • People are also reliant on closed ones.
Problems faced while navigating	6. Lack of receiving voice updates regarding location and directions. 7. People may misguide, when asked about directions and current locations. 8. Not enough technologies available based on needs. 9. Not receiving weather updates. 10. Existing developed technologies have language barriers and are too expensive. 11. The vibration alone from the smart white cane is not enough.	• Negative emotions and feelings. • Lots of problems are faced while navigating. • Mainly, the lack of voice-assisted software.
Improving the situation	12. Instruction-based and voice-assisted devices may be helpful. 13. More awareness among people. 14. A full set with an ear phone, white cane and voice-assisted software would be more helpful, instead of just one. 15. Better if the software operates in English and in my native language. 16. Worried about instruction-based systems of interfering with the surroundings.	• Hopeful and somewhat worried feelings about the improvement. • An integrated set is mostly preferred by almost all the participants. • Emphasis on awareness was seen too.

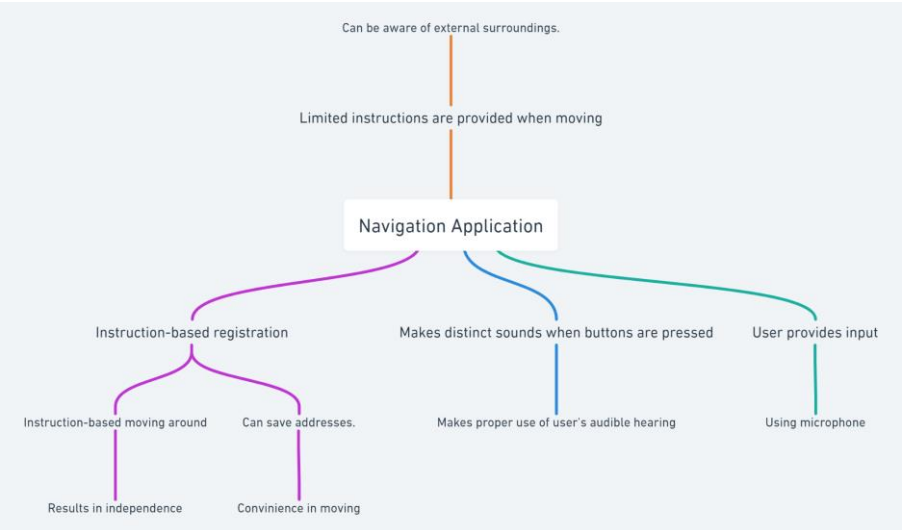

Figure 1. Mind-map

2.2.4 Phase 4: Prototype

In this phase, two types of prototypes of the navigation application are proposed, which may vary in terms of layout. Furthermore, the user flows, low-fidelity prototypes, and high-fidelity prototypes are also built. In this step, the unique solution is translated into a working prototype. During this step, the ideas and references are drawn from the previous phases and also the literature review. The working prototyping is made using Adobe XD, Figma and Flutter in Visual Studio Code.

Prototype 1 has 7 user flows, which is registration, login, hear tips, homepage (when logged in before), knowing current location, go somewhere new, and go to saved address in English and the same seven user flows in Bangla as well. The translation is done keeping code (10) and (15) in consideration, in which the participants express their discomfort in not being able to use the devices in their own language. Figure 2 shows the registration flow.

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Figure 2. Prototype 1 with registration user flow (English)

Registration user flow is the user flow that the user has to go through when they open the NavAssist application for the first time. As soon as the user opens the application, they hear the audio descriptions accordingly and decide if they want to register or log in. Few basic details are needed for the registration process. This instruction based and voice assisted application caters to code (12) instruction-based and voice-assisted devices may be helpful and code (11) the vibration alone from the smart white cane is not enough. Furthermore, the users can translate to their native language, Bangla, any time, by pressing the button at the top-right corner, which undoubtedly caters to code (10) existing developed technologies have language barriers and are too expensive and code (15) better if the software operates in both English and my native language.

The second user flow is the login flow. This is when the users get the application for the first time and are presented with the option to either register or log in. In order to log in the user only has to enter their password. This simple login is done in order to make the process more convenient and faster for the users. This can also be translated to Bangla in the same way. The hear tips user flow (Figure 3) comes after successfully registering or logging in for the first time.

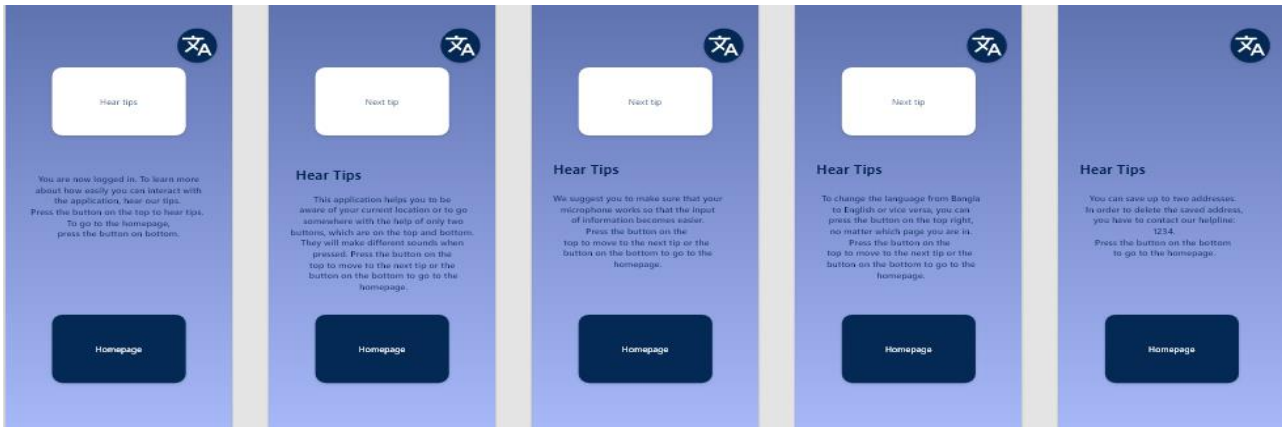

Figure 3. Prototype 1 Hear tips user flow (English)

In this user flow, the user can hear tips, which explains about the functionalities and the features of the NavAssist application. It explains the two main functionalities of the application, which is to know their current location and also to go somewhere. In prototype 1, the three different buttons present in each screen will make three different sounds when pressed. This is in conjunction with code (11), which states that the vibration alone from the smart white cane is not enough. The users are also informed about how they can change the language anywhere anytime by pressing the top-right button. Furthermore, they are also suggested to keep their microphone in check as they will be inputting information through speech. Lastly, the feature of saved addresses is also presented to them. They are able to save up to two addresses and as changing may be difficult for the blind users, they have to call the helpline in order to make any changes. This also makes them more independent and not rely on friends and family members as they can make the changes by themselves by calling on the helpline, which accounts for the independence code (3), (4) and (5). As they enter the already downloaded application, they will be presented with the two main functions of the applications, which is they can go somewhere and they can know their current location as well. This caters to code (7) people may misguide when asked about current direction and current location and code (8) not enough technologies available based on needs (Figure 4).

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Figure 4. Prototype 1 Already logged in homepage user flow (English)

The fifth user flow (Figure 5) is the user flow of finding out the current location. When the user presses on the current location, that is the bottom button, the user is told about their current location, resulting in solving the concerns regarding being misguided by people.

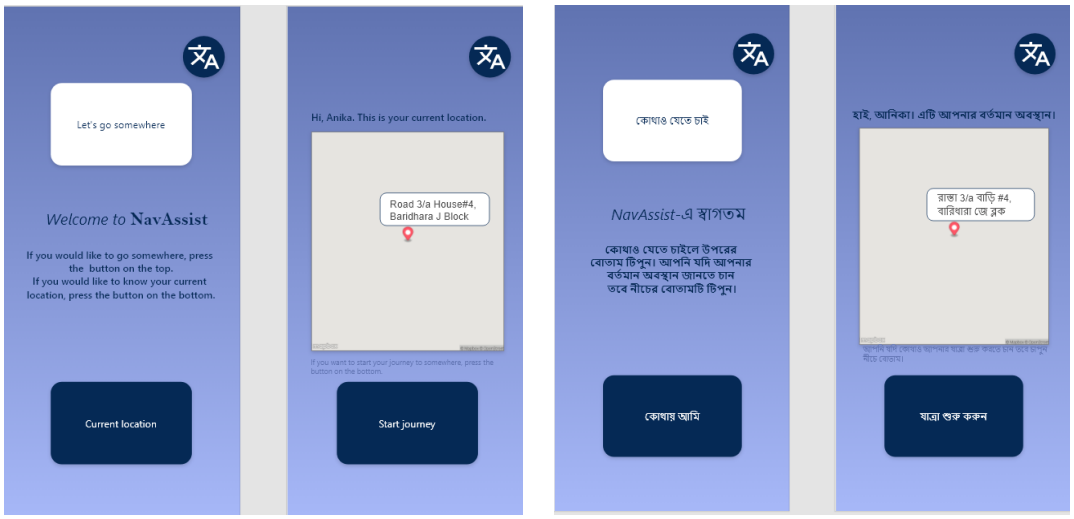

Figure 5. Prototype 1 Current Location user flow (English)

From the current location, the user will also be given instructions on how they can start their journey so that navigating through the application from page to page is also more convenient. Next, is the user flow of “Let’s go somewhere (Go somewhere new), where in this flow, the user has to input the address using the microphone and begin their journey. At first, the user presses “Let's go somewhere”, which directs them to a screen that provides them with the option of going somewhere new and also going to saved addresses. When the user presses “Go somewhere new”, they are asked to input their address, choose their mode of transportation, which is either bus/car or walking in this case. After they choose the mode they will be given simple instructions, which are easy to follow. They are also reminded to carry their white cane with them, which caters to code (14), in which participants express their desire of having a full set of devices when they are going outside along with that application. One thing to note is that on the screen in which they can enter the address, there is also a button on the top left. This helps them to save the address, while entering the address. The instructions for this task are also given.

Moreover, the application fulfills the weaknesses of the white cane, such as not being able to give full instructions and the white cane covers for the applications inability to provide the user with the ability to detect obstacles surrounding them. Overall, it is a well-rounded combination. Furthermore, the participants can also stop and change the location any time. In that case, they will be directed to the screen that lets them make a choice between going somewhere new or choosing saved addresses. Lastly, go to saved address user flow, demonstrates the flow of going to an address that is previously saved by the user. The flow is very similar to the flow of going somewhere new, but the user gets to choose

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from the saved addresses. When the user presses “Go to saved addresses”, the saved addresses are displayed and after the user clicks on one, they get to choose the mode of transportation. They are directed to the map and short instructions are provided. After they reach their destination, they can go back to the homepage.

For prototype 2, the features, functionalities, and the navigation flows are the same as they account for the necessary codes discovered during thematic analysis. In order to see the effectiveness of the user-interface and user-experience, the difference lies in the placement of buttons and the sounds when buttons are pressed. The size of the buttons and the instructions provided are kept the same. However, the audio descriptions vary a bit as there are changes in placements and sounds. In prototype 2, the two buttons are placed in the center and the bottom and in the given instructions “center" and “bottom” are also mentioned, whereas in prototype 1 only “top” and “bottom” are mentioned in the audio descriptions. Other than that, in prototype 2, all of the buttons make the same sound when they are pressed, whereas in prototype 2. Figure 6 demonstrates two screens of prototype 2, and how the buttons are placed.

Figure 6. Prototype 2 Excerpt (English and Bangla)

2.2.5 Phase 5: Test

This is the phase where the blind users use the working prototype and provide feedback. It helps in comprehending if the design actually works for the users. This phase takes place after the working prototype is fully developed. The two types of prototypes are compared in terms of how blind users interact with the application. This phase plays a vital role in further improving the prototype and understanding the effectiveness of each type of prototype. A/B testing will be done. A group of different participants is chosen to test the two different prototypes on two different days. The participants for the A/B usability testing are gathered with the help of the organizations mentioned before, BERDO and VIPS. The testers’ participation in the phase is fully voluntary. A total of ten participants, 5 (3 male, 2 female) for day-1 and 5 (2 male, 3 female) for day-2 are recruited. They are of different professions and their age ranged from 18 to 60 years. The testing takes place in the offices of these notable organizations in a span of two days and the results are analyzed later. A total of 1 hour is spent with each participant. The first 20 minutes is utilized for the participants to go through the user flows, input information, and lastly actually navigate from one place to another using the application. The next ten minutes is used to collect the quantitative data, using Google forms. The rest of the 30 minutes is utilized to conduct the interview and to gather data in qualitative form. The test is conducted one participant at a time. The two kinds of data will be analyzed after the interview is conducted.

3. Results and Discussion

3.1 Qualitative results

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Table 2. Qualitative results

Key Points	**Quotes and Analysis**
Navigating in a real-life setting using the application.	Most of them find it fairly convenient. P1 quoted, "*...not that much difficulty is encountered. The three devices are a good combination.*". P2 and P3 quoted, "…*it is a better experience than only going out with a white cane*". P3 also mentioned that the features, particularly the hearing tips flow, makes them feel more independent. The overall feelings are positive. However, one participant expresses concern about whether it will be as easy in a very noisy setting. P4 quoted, "…*although the initiative is good. It worries me about how I will be when I am in a very crowded place.*" For the next question about the features and the functionalities, the response is all positive.
Features and functionalities	The features and functionalities seem quite impressive to all the participants. P3 quoted, "*I like how I can translate any page to Bangla any time I want to, and vice versa. Makes the whole process so much easier for me*.". It can be said that the anytime translation feature clearly impressed all participants. One of the participants also mentioned that the current location feature is interesting and the flows are easy to follow as well. P5 quoted, "…*it's easy to go from one function to the other in the application. Didn't find it difficult*.". Lastly, when the participants are asked about the UI/UX aspects, such as button placement, audio descriptions, and inputting information, the response for the button placement and audio descriptions are positive. P2 quoted, "*I was actually surprised by how easily I could reach the buttons by following the spoken content*.". One of the participants also gives a different, but an interesting point of view. P5 quoted, *"I think the way the buttons are placed, your fingers also get used to the placement*.". This depicts that the users are able to get used to clicking and pressing patterns. However, when it comes to inputting information using the microphone, not all responses are positive. Participants have a more neutral perspective on it.
Inputting information	As compared to the other aspect of the application, the inputting of information when registering or logging in does not seem as easy. P4 quoted, "*...experience with inputting information was alright*". However, almost all of them show a more understanding tone. P2 quoted, "*I understand that registration and logging are one-time tasks, so maybe it's not as much of a problem*". The reason for the difficulty as suggested by the participants is that they are not used to inputting details like this using the microphone. not all responses to information input via the microphone are good. Participants are more objective about it. In comparison to other aspects of the application, entering information while registering or logging in does not appear to be as simple. "*...experience with inputting information was OK*," according to P3. Almost all of them, though, have a more understanding tone, just like the participants in prototype 1. "*I realize that registration and login are one-time procedures, so maybe it's not as big of a deal*," P2 said.
Traveling in real world with the app	When asked how they feel about traveling in a real-life scenario using the app, most users say it is quite useful. According to P2, "*...not much trouble is faced." The three gadgets work well together*." According to P1, "*it is a greater experience than just walking out with a white cane*." However, one participant questions if it will be as simple in a loud environment. "*...but I like the way it works*" said P5. The response to the following question on the features and functionalities is unanimously positive. All of the participants find the features and functions to be pretty amazing. "*...I enjoy how I can translate any page to Bangla whenever I want, and vice versa*," P1 said. It simplifies the entire procedure for me." All participants on both days were definitely impressed by the anytime translation capability. One of the participants also commented that the current location feature is fascinating, and that the flows are simple to follow. According to P3, "*..it's simple to go from one function to the other in the program." It wasn't tough for me…"*
UI/UX components	Finally, when participants are questioned about UI/UX components such as button placement, audio descriptions, and entering information, they respond positively to the audio descriptions. *"I was genuinely shocked by how easy I could understand the spoken content*," said P1. The top and bottom button arrangement, on the other hand, does not work because participants believe the top button is difficult to reach and may become confused with the other buttons on the top. Almost every participant expresses this fear. P2 is cited "*...getting to the top button is challenging and a little concerning for me because there are other buttons available. What if I choose the incorrect one?*". P5 quoted, "*I don't think I understand what is meant by top here.*". Lastly, there are also mentions about the different sounds being more confusing by two of the participants.

3.2 Quantitative results

The mean and standard deviations of each of the six criteria, which are ease of use, comfort of hearing audio descriptions, button placement, moving from screen to screen, moving from one place to another with the app, and inputting information in the app, are found in the two prototypes. The scoring form used for quantitative data is given below:

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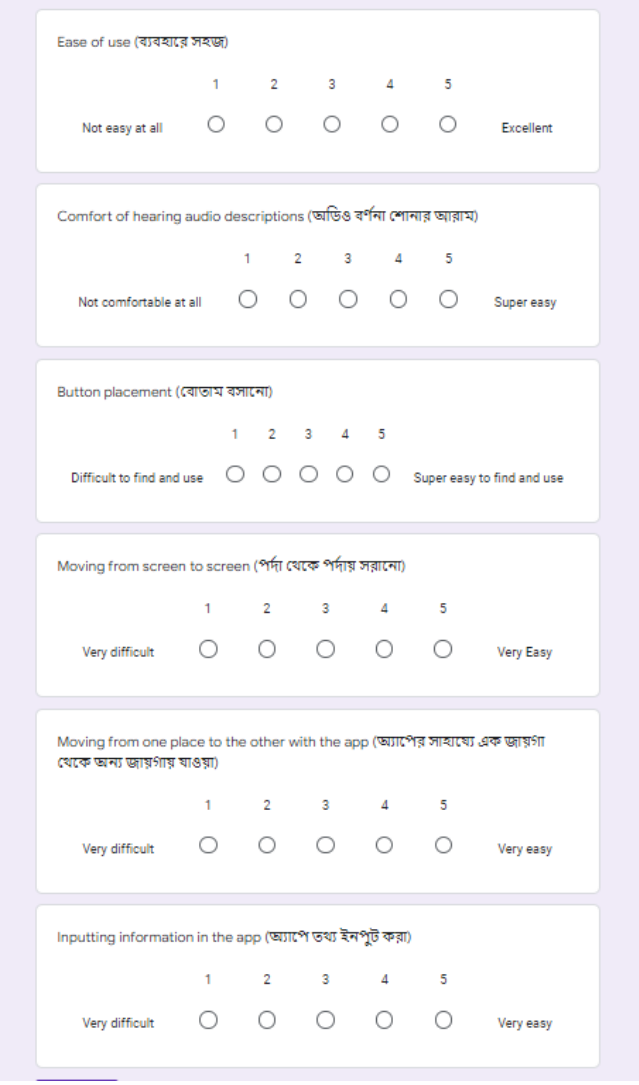

Figure 7. Quantitative data collection form

The mean and the standard deviation are then compared in order to see the effectiveness. The mean is the average of the scores given by all the participants. In this case, as a higher number indicates a positive response, a higher mean means that that particular prototype is easier to use. The quantitative results for prototype 1 and 2 are in Table 2. From the quantitative results, it can be deduced that almost all participants find the NavAssist application easy-to-use; however, inputting information using the microphone may not be as smooth as the other tasks. It is also evident that in terms of button placement prototype 2 performs considerably higher, which has an impact on moving from screen to screen as well. Participants find it easier to use if the buttons are within reach rather than being further apart or being too close to the two top buttons. Therefore, it can be concluded that proper spacing between buttons is essential for blind users.

Table 3. Quantitative results

	Ease of Use	**Comfort of Hearing Descriptions**	**Button Placement**	**Moving from Screen to Screen**	**Moving from One Place to the Other with the App**	**Inputting Information in the App**
Prototype 1	4.60 ± 0.49	4.80 ± 0.40	5.00 ± 0.00	4.40 ± 0.80	4.40 ± 0.80	3.60 ± 0.49
Prototype 2	4.60 ± 0.49	5.00 ± 0.00	2.40 ± 0.49	4.60 ± 0.49	4.40 ± 0.80	3.80 ± 0.40

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4. Conclusion

The results of the usability testing, in which both quantitative data and qualitative data is collected, show that prototype 2 is more effective and easier to use for the users. Prototype 2 scores significantly better on placement of buttons. The same kinds of sound when pressed also makes it less confusing for the users and it is something that they will get used to. Moreover, the center button is more preferred than the top button. This is because it is easier to access than the top button as the upper area also has the translation and the saved button, the user is more likely to make a mistake. Overall, the features and functionalities are preferred by both the groups. The feature of translating any time particularly impresses the users. The application is found to be easy-to-use and overall a positive attitude is displayed by all two user groups. Lastly, participants prefer a combination of three devices, which are the white cane, earphones, and the application. The mobile application is a significant part of it and by using it regularly they can navigate on their own, which can make them independent. In conclusion, future works can include replicating the same study in other regions and with a larger number of people. Furthermore, the UI/UX aspects of inputting information may also be improved. As mentioned before, the study can act as a good reference when developing applications for blind people.

Acknowledgment

We would like to thank BERDO and VIPS, the organizations we were in contact with during research.

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