Designing an Information Technology Based Voting Solution for Persons with Visual Impairment in Sri Lanka

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***Abstract*— Sri Lanka currently uses a paper-based voting system for conducting elections. In this system, voters with special needs have to depend on the assistance of another to mark the vote. Addressing this issue, the present study used the design science approach and attempted to create a voting solution for visually impaired voters. First, two focus group interviews were held with a sample group of visually impaired individuals with voting rights and election-related authorities and professionals. Finding of this initial data gathering identified two categories of interactions: (1) interactions for navigating and (2) interactions for selecting. Considering the capabilities and preferences of the sample, a prototype was designed together with the sample of visually impaired voters at a design workshop. The interfaces and design features were based on multimodality and universal design guidelines. Thus, two interfaces were designed using touch interfaces and buttons. A prototype with the interfaces was subjected to user evaluation. Feedback received for the prototype could be interpreted as that the voters with visual impairment prefer to use this multimodal voting solution if it is further improved in terms of layouts in the interfaces and flow of the interactions.**

Keywords-Electronic Voting; Visual Impairment; Accessibility; Privacy; Usability.

I. INTRODUCTION

Around 253 million people in the world live with vision impairment [1]. In Sri Lanka, about a million people with visual impairment have the right to vote, which is 5.1% out of the total population [2]. Persons with disabilities face immense challenges in realizing their voting rights despite the vast technological advancements taking place. Internationally, rapid progress is being made to ensure the persons with visual disabilities are given equal opportunities to exercise their democratic right of voting. For instance, United States has passed Help America Vote Act 2000(HAVA Act) [3], and Section 49N in The Conduct of Elections Rules, 1961 of India [4], has provided provisions to enable voters with different disabilities to vote. However, according to Elections (Special Provisions) Act [5] in Sri Lanka, it is allowed for a proven person with a disability (an eligible individual adhering to the stated requirements by the act) to be accompanied by someone who is capable of viewing a ballot paper, and mark the choice upon the preference of the voter [6]. Given that everyone deserves to vote privately and independently, it is doubtful that the prevailing polling process in Sri Lanka caters to the requirements of visually impaired voters. Skepticism arises as to whether the assisting personnel will maintain the secrecy of the vote and whether he will not breach the visually impaired voter's trust in casting the vote.

This research is an approach to design and propose an effective voting solution with the intention of addressing the difficulties faced by voters with visual impairments in Sri Lanka. The research question aimed to solve by this research is, "*What are the systems and interface design features required to provide a fruitful effective voting experience for the Sri Lankans with visual impairment*?". These features should enable an independent and accessible vote, which supports to maintain the secrecy of the vote.

Initially, interviews were conducted with the aim of understanding the context and requirements. Results from the interviews were analyzed. Subsequently, a set of design features were listed based on the knowledge which was obtained by the interviews conducted and the previously conducted literature review [7]. Afterward, a prototype was created, which is capable of demonstrating the listed design features. Moreover, a design workshop was conducted using the prototype to obtain feedback and suggestions from the voters with visual impairment. The results from the design workshop were used to improve the design features further. The remaining sections of the paper are organized as follows. Section II explains how the existing voting systems were analyzed in order to identify voting design features that support voters with visual impairment. Section III describes how the research was conducted while Section IV analyses the data and presents the results. Section V, VI and VII describes the solution design and results of the design workshop. Section VIII discusses the results and finally, Section IX concludes this paper.

II. BACKGROUND AND RELATED WORK

Various voting systems are utilized all over the world and a preliminary study was conducted through a literature review on the existing voting systems that support voters with visual impairment [7]. Table I shows the summary of the review conducted.

Paper-based voting systems provide advantages such that ease of understanding for the voter and default verification of accuracy due to the vote being directly caste by the voter. These systems are still being used by different countries even

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though they have not supported individuals who have visual impairments for independent voting [8] unless optical scanning or tactile methods are incorporated.

TABLE I. SUMMARY OF REVIEW OF EXISTING VOTING SYSTEMS

Topic	Findings
Design features relevant to accessibility	Tactile features • Buttons • Rotation dials • Sleeves with punched holes Touch features • Single/Double tap • Slide rule Multimodal features • Combining tactile, touch and/or voice input
Design features relevant to privacy	Security aspect • Cryptography-based solutions Interface aspect • Accessible interfaces • Screen off feature
Design methodologies	Design principles & guidelines • User Centred Design (UCD) • Universal Design (UD) Evaluation models • Unified Theory of Acceptance and Use of Technology (UTAUT) • ISO usability standards • System Usability Scale (SUS)

Most of the systems provide Braille buttons [9], but Braille literacy varies context wise. For instance, in Sri Lankan context, according to the statistics reported in 2003, 71% of visually impaired persons had some sort of schooling [10] but most were unable to use the Braille knowledge later on in their lives. Further, a study conducted in 2015 revealed that only 41% of the individuals who know Braille could use it [11]. In this backdrop, promoting Braille ballots is unsuccessful and unfair. Thus, it is important to have other modes of input and navigation, providing blind voters with the flexibility to choose a method they prefer. Catering this need, multi-modality concept and the 2nd universal design principle of Flexibility in Use [12] has been adhered. One such example is Prime III [13], an open source, multimodal ballot marking. For a completely blind voter, the accessible mode of interaction is the buttons with voice-based instructions. However, it has only 90% accuracy within an SNR (Signal to Noise Ratio) of 1.44 [14]. Additionally, in Prime III, a poll worker has to initiate the voting system and let the voter begin the voting process. Thus, it is being dependent on the assistance of poll worker while having space for voter coercion. Another system that adheres to the multimodal concept is Universal ballot design interfaces that provide two ballots, 'Quick ballot' and 'EZ ballot' [15]. In EZ ballot design, voting is made accessible to blind voters by adding slide rule [16] interaction design feature in the touch interface. Evaluations report that this slide rule is less familiar to blind voters and is poor unnatural interaction [17]. However, EZ ballot also has design issues, such as an accidental touch on unintended spaces and spending excessive time touching inactive areas due to lack of guidance on the touch interface [17].

In terms of ensuring the privacy of the vote, the majority of voting systems consider it as only a security aspect. Few systems (e.g., AVC Edge, AutoMARK VAT) have addressed interface level privacy by turning off the screen when a blind voter uses the system but the voters are not pleased by this feature [9].

In designing an information system, the best practice is to follow the guidelines. However, there is a lack of information and available evidence on how voting systems were designed. Only a few instances have been reported of design methodologies that have been followed. Among those voting systems, User-Centered Design (UCD) guidelines and Universal Design (UD) guidelines were followed for designing features, and System Usability Scale (SUS) has been used for evaluating those features more frequently. These standards and guidelines are to be applied across large domains where "they do not address functional issues since they cannot account for the intended users, activities, and goals of a product" [18]. Thereby even if using guidelines is a proper way to initiate designing a voting system, user feedback should be obtained both during the design process and after the design is finalized, similar to prototyping techniques [18].

III. RESEARCH METHODOLOGY

The present research aims to design a solution to support blind voters and it falls under the use-inspired design science [20]. Design Science is fundamentally a problem-solving paradigm [19] which has its roots in engineering and sciences of the artificial intelligence. The research was conducted following a methodology based on the design science research process (see Figure 1) by Offermann et al. [21].

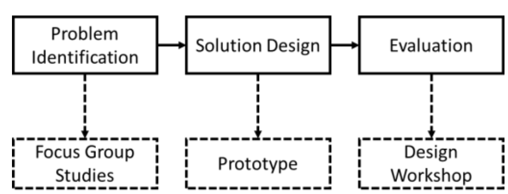

Figure 1. Research Model

In order to identify and solve the research problem, three studies were conducted. Two studies were performed by conducting interviews with two different focus groups. The results obtained from the initial two studies were used to design the ballot interfaces. The final study was based on a design workshop, which captured the interactions of visually impaired voters by providing a software prototype.

A. *Focus Group Studies*

Focus group interviews were conducted with two different groups. One group consisted of individuals from the election authority and election professionals. The other group consisted of voters with visual impairment.

Under the first focus group, one of the key people interviewed was the National Inclusion and Program Advisor of IFES (International Foundation for Electoral Systems) of Sri Lanka who has more than one year of experience in the relevant field. Also, she has worked as an independent consultant in disability rights, access, and inclusion for more than eleven years. Moreover, Additional Commissioner of Elections (Local Authorities) of Sri Lanka was interviewed. Semi-structured interview questions were used to obtain best-suited and more elaborated responses.

Later on, a group of voters with visual impairment were interviewed with the intention of understanding different types of individuals who the voting solution should be focused on. A questionnaire was constructed in a structured format. Succeeding, an expert evaluation was obtained for the questionnaire from the National Inclusion and Program Advisor of IFES. Here the information was gathered related to demography, level of visual impairment, usage of technology-based tools, usage of assistive tools, different literacy levels, and opinions on electronic voting. A sample group of nine (9) potential voters with visual impairments from the Sri Lankan Council for the Blind were selected by convenience sampling because reaching blind persons from all locations was not feasible. Further, it was convenient for the person who faced the interviews to reach a place of closer proximity. Before conducting all the interviews, consent was obtained from the participants ensuring the confidentiality of the information provided. Interview transcripts and notes were stored in MS Excel sheets. The collected data was analyzed and explained using appropriate illustrations.

B. Conducting a Design Workshop

After conducting interviews and gaining insights, the blind voter's journey in the voting process was identified as a sequence of steps in the proposed system. The solution was designed incorporating the identified design features and the prototype was created based on the designed solution. The design considerations of the prototype were discussed with the voters with visual impairments.

IV. Results and Findings of Focus Group Studies

The data collected from the interviews with election team (authorities and professionals) and our sample of voters with visual impairments were analyzed separately.

A. Interviews with Election Team

As explained in *Methodology Section*, the first set of focus group interviews conducted with election authorities and election professionals, contributed to understanding identifying the laws and procedures to be followed at elections and how elections are conducted. Elections in Sri Lanka consist of three major consecutive steps: (1) voter verification, (2) voting and (3) counting the votes. Voter verification takes place in three sub-steps where the polling officials check for a valid standard identification card, a valid polling card and verify whether the voter has not voted previously in the same election by any indelible ink left in the little finger. Once the verification is successfully completed, the voter is supplied with a ballot paper and is allowed to reach the voting precinct. Once the voter reaches the precinct, he or she marks the ballot and submits the folded ballot paper to the ballot box. Once the voting period is over, the counting process takes place and the results are announced. Voting in the election procedure is further divided into more steps based on the type of the election held. There are five types of elections taking place in Sri Lanka: presidential, parliamentary, provincial, local authorities, and referendum. Although several types of elections exist, there are only two - main variations among the election types: elections that require a vote for a particular political party only, and which both political party and candidate (preferential voting) required to be voted.

According to interviews held, there is no report of any research conducted for designing a new voting solution, which supports voters with visual impairment in Sri Lanka. However, all are looking forward to a change from the existing paper-based voting system to an electronic voting system, in the near future. In terms of supporting the voters with visual impairment, their opinion was that a digital voting system is the only solution to exercise the equal voting rights. Even though the existing law addresses only the paper-based voting system, according to election officials, actions will be taken to introduce an electronic ballot.

Election authorities expect features to ensure privacy, accuracy, and trustworthiness in a general electronic voting system. However, for a voting system, which supports voters with visual impairment, main concerns are to possess features that ensure accessibility and usability. Additionally, more features were mentioned, such as the ability to vote in a preferred language due to multi-ethnicity in Sri Lanka, clearness and preciseness in voting instructions on how to vote, a simpler solution that can address a long list of political parties and candidates without consuming a significant time to vote.

B. Interviews with Voters with Visual Impairment

The second set of focus group interviews were conducted with voters with visual disabilities. These interviews were contributed to identifying the demography, skills, and experience. Participant ages were in the range of 18 years to 67 years (Table II), where the average participant age was nearly 42 years (SD:17).

TABLE II. Demography and Blind Context of the Focus Group

Demography and blind context			
Age (years)	***Gender***	***Became blind at age (years)***	***Blind category***
18	Male	Birth	Total blind
21	Male	7	Partially blind
35	Female	23	Partially blind
37	Male	9	Partially blind
38	Male	Birth	Total blind
47	Female	43	Partially blind
53	Female	Birth	Partially blind
63	Female	Birth	Partially blind
67	Female	4	Total blind

Among the participants, three were totally blind and the remaining majority of participants were partially blind or have low vision with some slight variations in sight. It is observed that the age at which they have started experiencing a visual impairment is varied as shown in Table II.

Among the participants, the majority were literate in Braille (Table III) but when their preference of using Braille was questioned, 88.8% disliked. The reasons for the dislike were described as the continuous touch of Braille which causes fatigue in hand muscles, complexity in learning braille, and lack of teachers to provide Braille education. With the evolvement of new technologies, they prefer more to listen than reading in Braille.

TABLE III. BRAILLE LITERACY OF THE FOCUS GROUP

Strongly knows	55.5%
Fairly knows	11.1%
Slightly knows	22.2%
Does not know	11.1%

Moreover, experience in using mobile phones or Automatic Teller Machines (ATM), is considered a potential to use an electronic voting solution with ease implying that similar interfaces are incorporated [8]. Thus, participants were questioned of whether they have prior experience in using digital devices, such as an ATM, a computer, or mobile phones as shown in Table IV. All of them had some sort of experience in using these devices. Further discussions led to the understanding of their familiarity in using inbuilt accessibility tools, such as Talkback (by Android), Screen readers in computers.

TABLE IV. IT LITERACY OF FOCUS GROUP

Digital device/equipment	
ATM	11.1%
Computer	22.2%
Mobile phone with basic features	44.4%
Mobile phone with touch interface	66.6%

Participants were asked what functionalities they have used in mobile phones and how they have accessed those functionalities as the majority of participants were familiar in using mobile phones (Table V).

TABLE V. FUNCTIONALITIES AND INTERACTIONS USED IN MOBILE PHONES

Mobile phone functionality	Interaction	Percentage
Calling	Tap (Single/double tap)	66.6%
	Slide rule	33.3%
Messaging/typing	Tap (Single/double tap)	22.2%
	Slide rule	77.7%
Play music	Tap (Single/double tap)	88.8%
	Slide rule	11.1%
Using calculator/typing	Tap (Single/double tap)	22.2%
	Slide rule	77.7%

Participants who had prior experience in using smartphones were familiar with both interaction types found in smartphones which provide accessibility: Using single/double tap, and slide rule [16]. Moreover, usage of 'Slide Rule' was questioned because it was used in a previous study to design ballots for voters with visual disabilities. It is a one-finger scan and lift finger interaction [22]. They preferred slide rule for typing purposes like messaging and using a calculator. Moreover, they preferred tapping for selecting and navigating purposes like calling and playing music. When they were questioned further about their preferences, a majority of 83.3% liked the tapping (single/double tap) interaction over slide rule interaction. Some reasoned out stating that it is since the tap selections provide a way to confirm the selection made whereas few stated that tap selections felt intuitive and natural. Further, some explained that unintended selections are caused when the finger is dragged and released (Slide Rule).

Relevant to using touch interfaces, contradicting opinions were made where one participant mentioned the inconvenience to scan over the touch screen, which is time-consuming. Few others had opposing ideas stating that they prefer using touch phones because of the inbuilt or installable accessibility features.

Among the participants, 44.4% (Table IV) had the experience of using mobile phones with keypads. They explained that for navigation in menus, they are using the arrow buttons. For dialing numbers or typing messages, they memorize the keypad structure and the embossment mark on the number five on the keypad supports identifying the key locations. Irrespective of the experience of using mobile phones which only have keypads (not smartphones), every participant explained that it would be better if it is affordable. Thus, tactile buttons are used to design the voting solution. Two participants stated that a feature should be facilitated with the ability to change the color contrast.

V. DESIGN OF THE SOLUTION

Design of the solution is explained in detail through sub-divided sections of the voter's journey as design decisions and features, and interaction techniques.

A. *Voter Journey*

The journey of the voter with visual impairment starts when the voter wears the headphone as indicated in Figure 2. Thereafter, the audio instructions are initiated to play. At first, the voter is instructed to choose the preferred language. After the language selection, the voter is acknowledged about the 'settings' button by stating the options available that can be modified: language preference, audio volume, audio speed, and color contrast.

Succeeding the fact, the system directs the voter to the voting instructions. If the voter chooses to listen to the voting instructions, an approval from the voter is taken to make sure that he/she is ready to vote after playing voting instructions. After getting the approval the voting list is displayed mentioning the number of political parties/ candidates with the number of pages.

The voter can select the preference by pressing the appropriate button and confirm the vote. The system acknowledges the voter about the successful completion of the voting and requests the voter to replace the headphone. If the voter does not select any, the system replays the list automatically.

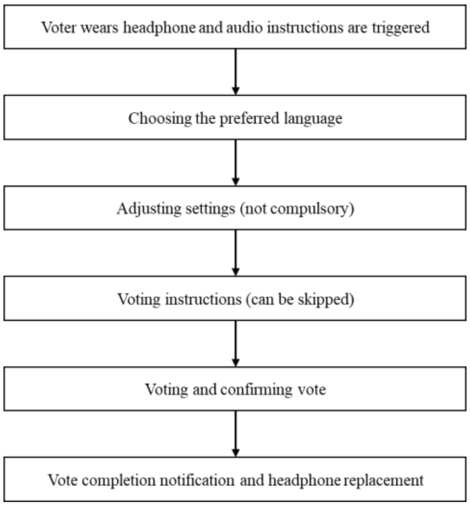

Figure 2. Flow chart of the journey of a voter with visual impairment

B. *Design Decisions and Features*

Table VI summarizes the design decisions and features of the suggested voting solution to support voters with visual impairment.

TABLE VI. DESIGN FEATURES AND JUSTIFICATIONS

Design feature	Justification aligning Universal Design (UD) Principles
Having button controls with unique features	*UD Principle 4: Perceptible Information* Satisfying both sub-principles in UD, buttons are with different shapes and colours are used as a tactile input because then, it is easily understood by persons with visual disabilities by feeling the shape of the button. Having differently shaped buttons also helps to guide the voter with instructions. Shapes and colors of the buttons based on the EZ control keypad [23].
To do a selection either of • Press 'select' • Touch the hole	*UD Principle 2: Flexibility in Use* Voters are given two methods of doing selections/voting. They can choose their preferred method.
Voting by listening to the list of political parties/candidates and press the 'select' within the given time interval	*Principle 3: Simple and Intuitive use* *Principle 6: Low Physical Effort* Here the complexity of voting is maintained by the simple press of a button while listening to audio clips. Also, it does not require high physical effort.
Voting by single tap/ double tap on the touch interface	*Principle 3: Simple and Intuitive Use* Voters being familiar with single tap/double tap interaction due to their experience in using smartphones.
Tactile sleeve with punched holes on top of the touch interface	*Principle 6: Tolerance for Error* Tactile sleeve acting as guidance for voters that would avoid touching unintended areas and less prone to errors that were reported in an existing voting system, which have touch interfaces [17].

Table VI explains the justifications for these features and how the Universal Design guideline has been followed.

C. *Voting Interfaces and Interaction Techniques*

A voting interface with both touch and buttons was designed based on the results obtained from the initial focus group interviews and previous literature review study (Figure 3). However, the findings of the interviews informed that there was a difficulty of scanning the whole touch screen in terms of using touch phones. Voting systems previously designed based on touch interfaces have also reported many issues due to the accidental touch [17]. Thus, a tactile sleeve was designed to act as guidance as shown in Figure 3. It shows that a tactile transparent sleeve with holes placed on top of the touch interface.

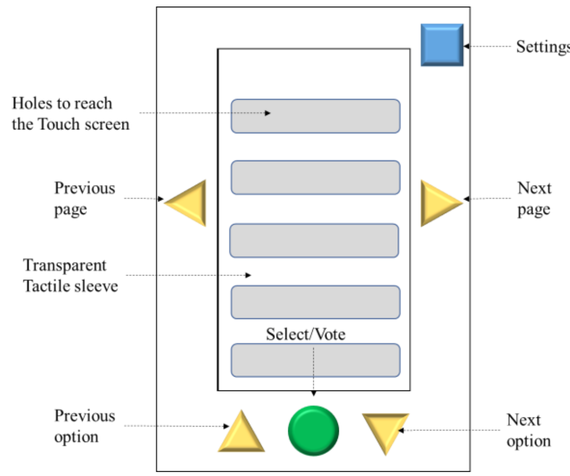

Figure 3. Voting interface with the tactile sleeve

As shown in Figure 3, the voter with visual impairment can vote using either the touch interface or using the buttons.

1) Using Touch Interface: In the touch interface, tap interactions on the holes in the tactile sleeve can be performed for both navigation and selection. The political parties or the candidates are listed on the voting page. When a hole is tapped once, the relevant political party/candidate is announced. If the voter requires to vote, the relevant hole has to be double tapped. Hense, the voter is asked to confirm the vote by tapping twice again throughout the audio instructions. Here, the transparent sleeve with holes is used as a guide to reduce the inconvenience of touching unintended areas and screen areas that have no response.

2) Using Button Interface: In the button interface, next option, previous option, next page, previous page, and settings buttons are used for navigation and select button (circular green) is used for selections as shown in Figure 3. Next option button and previous option button are used to navigate the previous and next political party/candidate.

The political parties or the candidates are announced through audio recordings. After each political party/candidate, there is a pause allowing the voters to cast their vote. If the voter prefers the particular political party/candidate, the voter should press the green circular button as indicated in Figure 3. Otherwise, the voter can wait till the system announces the next political party/candidate or press the yellow triangular button on the bottom right side. After a voter presses the green circular button, the voter is asked to confirm the vote by again pressing the same button.

VI. DESIGN WORKSHOP

The design workshop was conducted to obtain user feedback on the suggested voting interfaces by providing a prototype.

A. *Procedure*

A sample of eight persons was selected. There were four representing Sri Lankan blind council and four students from the University of Colombo in the sample. A pre-survey questionnaire was answered by the participants. Further, a set of six activities were conducted where each participant was allowed to attempt each activity a maximum of three times. After three attempts the participant was instructed to carry out the next activity. Observations were noted down during the activities and feedback was obtained after each activity. However, after obtaining the consensus of the participants, video recording was carried out for further study of observations.

B. *Prototype*

The prototype was built using MS PowerPoint slides to show the necessary content, a laptop with a touch interface, a tactile sleeve made out of rigifoam, rubber buttons and wireless headphone to play audio instructions as shown in Figure 4.

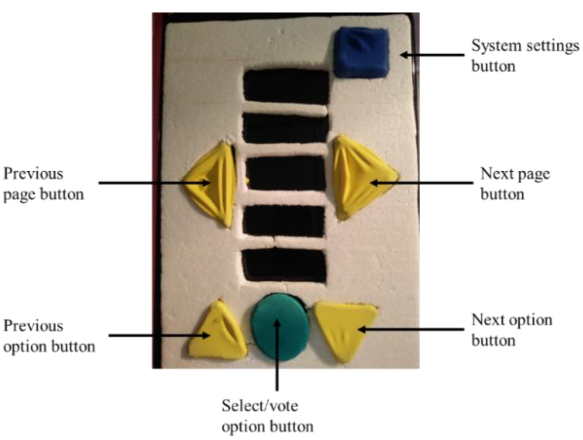

Figure 4. The prototype of the voting interface

The voting list was constructed using country names and the symbols show the animals used by the countries to represent their nation. A sample set of audio instructions were recorded by three voices and was subjected to expert evaluation by a voice expert from Sri Lankan Broadcasting Corporation. Furthermore, before using the voice clips in the prototype, the necessary modifications were made in the instructions considering how the speakers should convey the instructions. Figure 4 shows how the tactile sleeve appears when the screen is off. The feedback and observations of using the prototype are identified in three categories: touch interface with the tactile sleeve, button interface, and audio instructions.

C. *Participants*

Participant's ages were in the range of 20 years to 74 years (Table VIII), where the average participant age was around 40 years (SD:20).

TABLE VII. DEMOGRAPHY AND BLIND CONTEXT OF FOCUS GROUP

Demography and blind context					
Age (years)	***Gender***	***Became blind at age (years)***	***Blind category***	***Smartphone experience***	***Single tap/double tap vs Slide rule***
20	Female	Birth	Total blind	Yes	Tap
25	Male	10	Total blind	Yes	Slide rule
25	Female	15	Total blind	Yes	Tap
28	Male	Birth	Partially blind	Yes	Tap
33	Male	17	Partially blind	Yes	Tap
47	Female	43	Partially blind	Yes	Tap
67	Female	4	Total blind	Yes	Tap
74	Male	10	Total blind	Yes	Tap

Among the participants, three participants were partially blind and the remaining majority of participants were totally blind. All the participants had the experience of using smartphones.

VII. RESULTS AND FINDINGS OF DESIGN WORKSHOP

The results have been analyzed to find the effectiveness of button and touch interactions and the audio instructions.

A. *Button Interface:*

In the **first activity**, the participants were instructed to find the buttons one by one. Figure 5 shows how the participants were able to locate the buttons. All the participants were able to recognize the 'select' button, 'next' button, and 'previous' button in their first attempt. However, the 'next page' button and 'previous page' buttons were not identified by 88% of the participants in any of the attempts. Also, only 25% of the participants were able to identify the 'settings' button in the first attempt and the remaining participants were able to identify it at the second attempt. Most of the participants who identified the 'settings' button in the second attempt, pressed the 'next page' button mistakenly in the first attempt. One of the participants stated that 'I did not think that this device has that much length. So, I did not take my hand that far'.

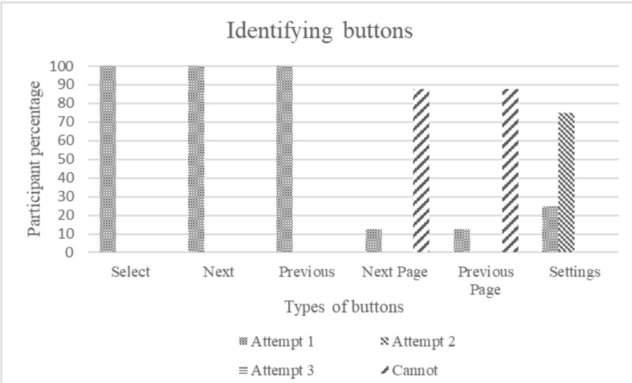

Figure. 5 How the focus group identified buttons

Another participant with partial blindness mentioned that contrast of yellow color of triangular buttons and green color of the circular button is not sufficient and that it confuses the user.

The **second activity** was to identify the function of the buttons. The button functions were described to the participants and they were asked to press the correct button relevant to a particular function. For instance, in order to identify the 'settings' button, the participants were instructed "Press the button required to navigate to Settings" The instructions were provided to try out all the buttons: select, next, previous, next page, previous page, and settings. All the participants were able to identify the 'select' button and the 'settings' button at the first attempt but several attempts were made to identify other buttons as shown in Figure 6.

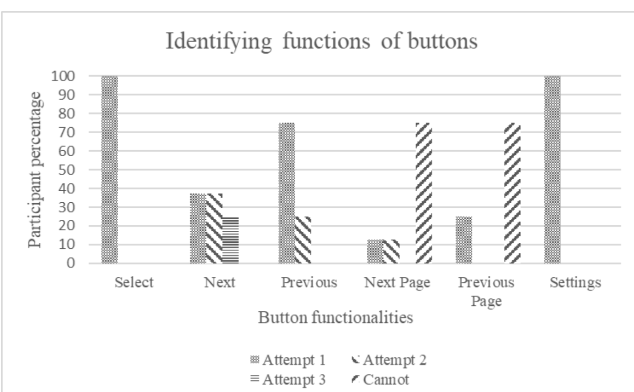

Figure 6. How the focus group identified functions of the buttons

63% of the participants could not figure out the 'next' button in the first attempt. It was observed that they pressed the 'previous' button when they were asked to press the 'next' button. Even though they made several attempts to identify the 'next' button, they easily identified the 'previous' button (triangular button on the bottom left).

Only 25% of the participants were able to identify the 'next page' button and the 'previous page' button. The remaining 75% of the participants pressed the 'next' and 'previous' button instead of pressing 'next page' and 'previous page' buttons respectively. Some participants stated that having pages and navigating through pages is uneasy for them.

Some stated that the space between buttons should be increased and few suggested that the button shapes can be easily identified if the button sizes are reduced up to an extent. The majority stated that shapes are unique and that they can figure out what they are while few suggested that it would be better to have a mark on the triangular shaped buttons to differentiate between previous and next functions.

B. Touch interface with the tactile sleeve:

In the **third activity**, the participants attempted to identify and touch the five holes on the tactile sleeve from the bottom to the top (1st hole, 2nd hole, 3rd hole, 4th hole, 5th hole). All the holes were identified by the participants but the attempts at which the holes were identified varied slightly as shown in Figure 7.

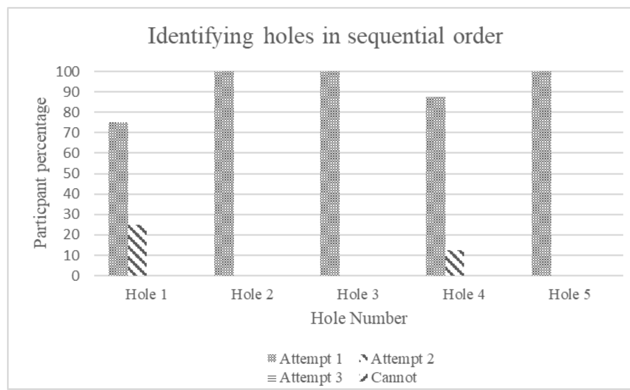

Figure 7. How the focus group identified holes in sequential order

All the participants identified the 2nd, 3rd and 5th hole at the first attempt. 75% of the participants identified the 1st hole in the first attempt but 25% identified it in the second attempt. One of the participants who could not attempt correctly in the first attempt stated that "I could not figure out where the holes started".

The **fourth activity** was to identify and touch the holes in a random order (2nd hole, 4th hole, 3rd hole, 5th hole, 1st hole). Similarly, as in Activity 3, the participants were able to identify all the holes in different attempts. All the participants were able to identify the 5th hole or the last hole. It was noted that the 4th hole was identified correctly in several attempts as in Figure 8 but identifying the 3rd hole showed a greater success. The participants explained that identifying 3rd hole was easier since they knew where the 4th hole was located.

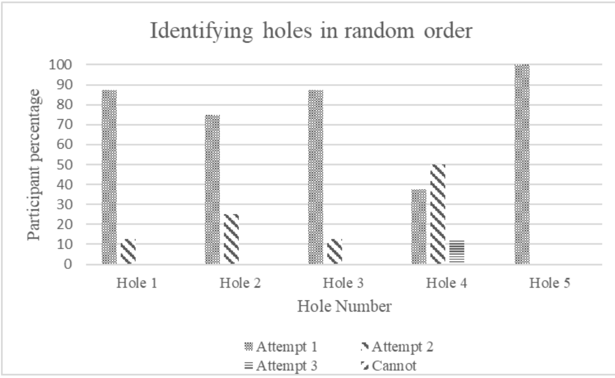

Figure 8 How the focus group identified holes in random order

Similar to the results of the third activity, the participants responded commenting that the starting hole of the device was not easily identifiable.

In the **fifth activity**, the participants attempted to vote for the instructed political party. The objective behind this activity was to identify their ability to perform single tap and double tap with the touch interface as shown in Figure 9. Here, the participants were asked, ‘What is the political party represented by the 1st hole?”.

They are expected to perform a single tap on the 1st hole, which resulted in playing an audio clip that announced the political party represented by it. Only 50% were able to do a single tap correctly at the first attempt while 12.5% were unable to perform. It was observed that they performed a double tap instead of a single tap.

Thereafter, the participants were asked to vote the same political party and they were expected to double tap to vote. This was successfully performed by all participants at their first attempt.

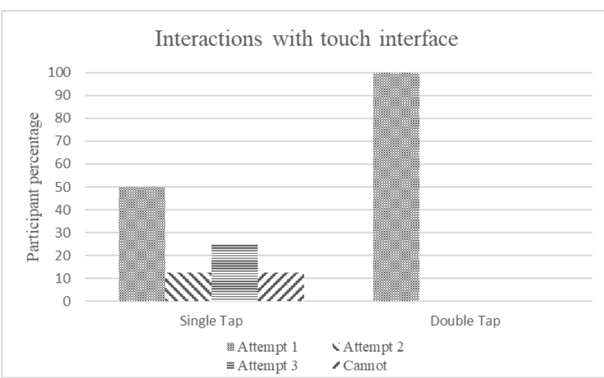

Figure 9. How focus group performed interactions with the touch interface

It was observed that all the participants were having the grip on the device by their left hand and were pressing the buttons only with their right hand. The same observation was made in how they used the tactile sleeve.

C. Audio instructions

Finally, it was required to find a suitable time interval, which acts as the maximum waiting time for a voter’s response to a given audio instruction. For this purpose, as the **sixth activity,** the participants were asked to press the ‘select’ button when a particular political party is played by the audio clips. These clips were played with 3 seconds, 4 seconds and 5 seconds time intervals.

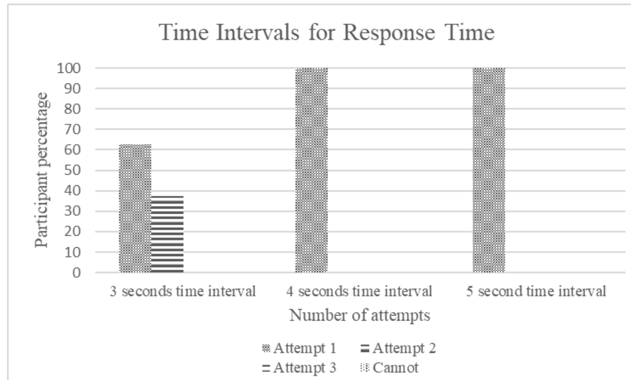

Figure 10. How the focus group performed at different time intervals for response time

All the participants were able to vote within 4 seconds and 5 seconds time intervals in the first attempt but only 62% were able to vote within 3 seconds time interval in the first attempt (Figure 10). From the feedback received, 62% mentioned that 3 seconds were sufficient but remaining stated that at least 4 seconds time interval is required.

D. Preferences

Participants were asked to choose their preference between the two methods of suggested voting

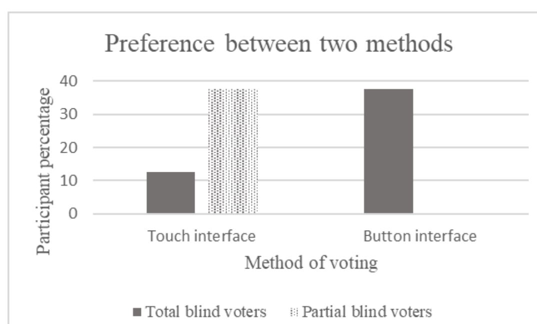

Figure 11. Participant preference on using the two methods and their blind category (percentage wise)

It was observed that the partial blind voters preferred more in using the touch interface with the sleeve and total blind voters preferred more in using buttons interface (see Figure 11). Participants who preferred the touch interface explained that it helped them to touch the appropriate places without having to touch the whole screen. Participants with total blindness suggested that the touch interface design can be further improved if some guidance is presented to track the holes instead of having to guess or remember the locations of the holes. It was observed that participants required more space on the tactile sleeve without buttons, where they can rest their hand. It was stated that the sizes of the holes are sufficient but the space between holes required to be increased. Two participants stated that having five holes is familiar to them and another participant stated, "it is not hard to identify 5 holes. 5 is easy. I think I can figure out even more".

VIII. DISCUSSION

From the interviews conducted with voters with visual impairment, it was understood that almost everyone had some sort of experience in using mobile phones. However, their experience in using different types of mobile phones varied. The majority (66%) had the experience of using smartphones but there were persons who had only the experience of using a basic mobile phone with buttons or keypads. Thus, in order to interact with the voting system, voters should be provided with several modes such that they will choose the most familiar mode, which is bringing in the multimodality concept for voting. The availability of more than one way to navigate or use the system is accommodating the 2nd Universal Design principle of Flexibility in Use [12]. Few systems are designed based on this concept whereas certain challenges remain that needs to be addressed. As mentioned earlier in the introduction section, voice-based voting is claimed accurate only within certain environments with respect to sound distortions. Thus, it leads to the discussion of tactile (using buttons) voting and touch-based voting.

Tactile voting is facilitated by a button interface, which has buttons in different shapes that are uniquely identifiable in different locations satisfying the underlying 4th universal design principle of Perceptible Information [12]. Button shapes and colors were designed similar to the EZ control keypad, which is used by some existing voting systems as an assistive tool [23]. Based on the evaluation and feedback by the focus group users of the design workshop it was discovered that colors have to be refined because some blind persons have difficulties with respect to color contrast. Additionally, this shows that solely depending on color is also not sufficient. Thus, different shapes were used to improve the uniqueness of the buttons. According to the prototype results, 'next' and 'previous' buttons were identified by trial and error even after providing instructions. Thus, those buttons should be placed together, giving a natural intuitive feeling of going up and down rather than placing on the right hand. Although it was attempted to make the buttons easily identifiable by keeping the buttons in different locations, results showed it was inconvenient for the blind voters. For an instance 'settings' button was far away for the participant to approach. Thus, buttons should be placed at close proximity. Next page and previous page buttons made less sense to the participants. They considered the 'next' button as 'next page' and 'previous' button as 'previous page' button. Instead of going through pages, the suggested approach is to consider a single page, which can be scrolled down from 'next' option after every five political parties/candidates. This is more intuitive as it is more similar to the paper-based voting, where only a single long ballot paper is provided for voting in the Sri Lankan context. In existing voting systems with touch interfaces [17] some inefficiencies were reported and identified as in the literature: accidental touch, vote-changing errors, unfamiliar touch interaction, tapping inactive areas. These inefficiencies can be reduced by allowing voters to reach only the active areas in the touch interface by the support of a transparent tactile sleeve with holes aligned with voting options. Thus, to mark the preference, the voter can listen to the voting list announced via the audio sequentially and vote for the desired by pressing button controls or tapping on the screen. Prototype evaluation results informed that users are capable and prefer to use the tactile sleeve. However, it was observed that some participants used trial and error in tracking the holes. Thus, improvements have to be made by including a feature as a guide to track the holes, so that they do not require to remember the holes or guess.

In the present study, in order to interact with the touch interface, tapping method was used instead of 'Slide rule' [16]. The slide rule was not considered since it could be less natural for blind voters [17]. This consideration confirmed the findings of the interview and the workshop pre-survey. Even though a single tap is performed when using smartphones to listen to a description, prototype results showed that majority of the blind persons are familiar with double tap more than a single tap. But there were also some participants who were familiar with a single tap gesture. Thus, in order to listen to a description or make any kind of selection (selecting settings options, vote, confirm, etc.) tap can be allowed, where no restriction is placed. As in here, after any tap gesture (single or double), a description of the selected area is described and the voter is asked to tap (single or double) again if it is required to be selected.

IX. CONCLUSIONS AND FUTURE WORK

The focus group studies with authorities ensured that there is a necessity of having an accessible voting solution designed which supports the persons with visual impairment in their voting process. Henceforth, it was reported that no research has been conducted in Sri Lanka with regard to this requirement.

The focus group study with the sample of voters with visual impairment showed that they are familiar with the touch interfaces as they have experience in using smartphones. Equally, some showed their interest in using keypads. These findings resulted in designing a multimodal voting solution incorporated with Universal Design

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principles. The prototype was tested through a design workshop.

However, the interfaces were tested only for the voting step and no other steps such as language selection, adjusting settings, etc. Also, the full comprehensive system was not developed in this stage but has to be created after making necessary improvements reported in this paper. After implementing a full solution, comprehensive evaluation method should be used such as System Usability Scale or following ISO Usability Standards.

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