Everyone Counts: Voting Accessibility

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Abstract. There are approximately 37.5 million disabled Americans of voting age. Current voting technologies have failed to provide Americans with disabilities a voting system that allows them to vote without assistance. Through the use of natural interaction a voting system called Prime III provides a secure and usable voting system for all voters regardless of ability. Prime III was recently tested at the Alabama Institute for the Deaf and Blind in which a number of Americans with various disabilities had the opportunity to vote. Participants were tasked with casting their vote using Prime III. The results of this study showed that Prime III allowed voters who where blind, and/or hearing impaired the ability to cast their vote without any additional assistance. The participants noted that Prime III was easy to use and trusted the system to successfully cast their vote.

Keywords: E-Voting, Universal Access, Multi-modal Interfaces.

1 Introduction

According to the American Association of People with Disabilities, in the United States there are 37.5 million disabled people who are eligible to vote [1]. In October of 2002 Congress passed the Help America Vote Act that required all states to replace Punch Card systems with new election technology that allowed people with disabilities the opportunity to cast their ballot accurately, secretly and independently. For many voters this would be their first time being able to vote without someone assisting them. One disabled voter said, "It's a great experience to be able to vote independently and in secret for the first time [2]."

While current voting system manufacturers make claims that everyone can vote independently, these systems fall short when it comes to the usability of the system. The AVC Edge is one of these systems. AVC Edge is a touch screen unit that uses Braille buttons for the visually impaired. The problem with the AVC Edge is that it makes an assumption that most blind voters can read Braille. Although estimates vary, there are approximately 10 million blind and visually impaired people in the United States with 1.3 million of them registered as legally blind. There are approximately 5,500 legally blind children that use Braille as their primary reading medium; however, there are approximately 55,200 legally blind children [3]. These figures clearly indicate the Braille illiteracy at 90% or higher. With Braille illiteracy being so

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high, the use of Braille buttons doesn't generally supply the visually impaired community with an adequate means of voting.

AccuVote-TSX produced by Premier Election Solutions is another voting machine with accessibility features that are geared mostly to the visually impaired. This voting system, has a touch screen that can be adjusted for those in a wheelchair, an on-screen magnifier for low vision, playable audio and a numeric keypad for the visually impaired. In order for the voting process to start the voter must insert the voter identification card that was given to them by the election administrator. There are two problems with this approach; expecting the voter to insert the identification card and expecting a visually impaired voter to be familiar with a numeric keypad.

The e-slate voting system addresses the issue of equal access voting by requiring both sighted and visually impaired voters to use a push button interface with a dial that the voter rotates to scroll through the ballot. It also expands to where quadriplegics can connect their sip and puff devices that will allow them to vote using their mouth. The e-slate makes a good attempt at usability however the buttons are too close which can cause accidental selections. Additionally, the rotating dial is too close to the enter button; voters could accidently hit the enter button while rotating the wheel causing unintentional selections. The e-slate does not fulfill Section 508 of the Accessibility Guidelines of the Rehabilitation Act which states that "Controls and keys shall be operable with one hand and shall not require tight grasping, pinching, or twisting of the wrist [4]". Whether you are a voter with or without a motor impairment holding the e-slate in one hand and still being able to rotate the dial is impossible. There could also be confusion on when to use the different buttons on the interface due to the wording. If you were not familiar with this style of physical interfaces how do you know when to use the select dial or the enter button. To a voter who is less knowledgeable in physical interfaces like e-slate's the select dial looks like a circular button, there is nothing that tells the voter that it is meant to be rotated and not pushed.

The goal in creating a voting system should be to make the interface and interaction natural, such that everyone can use it without having specialized knowledge prior to stepping into the voting booth. Such a voting system has been developed that uses technology to facilitate natural interaction. This natural interaction should provide a means for allowing all voters regardless of ability or disability the opportunity to participate in the voting process and be confident that their vote is confidential.

2 Prime III

By using a user centered design approach and rigorous security mock-ups, an open source multimodal electronic voting system was developed that shifts the voting paradigm. This new voting system is called Prime III, seen in figure 1. Prime III is designed to be a standalone system or an add-on to current voting systems. Prime III uses a touch screen monitor and headset with microphone to facilitate a natural means of interaction.

The multimodality of Prime III is what allows all voters regardless of ability to cast their vote without any assistance on the same machine. What this means is that

disabled voters do not have to use a separate voting system. The following describes the interface of Prime III followed by the unique interaction provided by Prime III.

The touch screen interface as seen in figure 1 takes into consideration various disabilities that may affect the way a voter votes. One such consideration is color blindness. The Prime III color scheme seen in figure 1 is designed to accommodate voters with color blindness. The interface also takes into consideration voters with physical impairments that limit their dexterity, by having large buttons which provide ample pressing space. Large text is also provided so that voters will not have difficulties reading the screen. Also note that in figure 1 there is only one race displayed. This removes the potential of voter confusion and possible under voting. Previous elections have had issues of under votes when the voting interface had more than one race per screen [5, 6, and 7].

The Prime III interface also highlights the number of races remaining. This is done because Prime III requires the voter to go through each race. This ensures that there are no under votes from accidentally missing a race. The voter does not have to vote for each race and can skip to the next race by choosing continue.

When making a selection there is a short delay to address double clicking or finger dragging as observed in voters with shaky hands. Some touch screen systems make immediate selections; therefore, double clicks will put the second click onto the next screen and select the next option on that screen. Essentially, this is equivalent to clicking once, waiting for the screen to display and clicking again in the same spot. When a double click occurs, the voter either doesn't see the second screen or believes that the system has made a selection for them.

One last note is the voter verification process of Prime III. Prime III has a unique way of allowing the voter to verify their ballot. First, the voter has to view two verification screens.

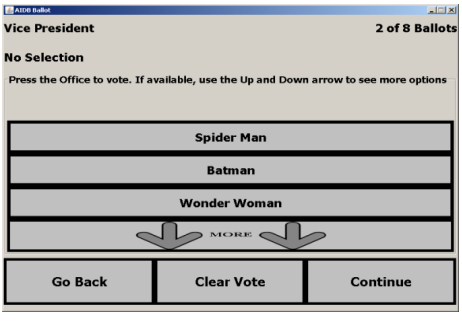

Fig. 1. Prime III User Interface

The only difference between the two verification screens is the labeling of the buttons. The initial verification page has a button labeled "Continue". The final confirmation page has a button labeled "Cast My Ballot" located at the bottom of the screen. On the first of the two confirmation screens, the voter views the votes made during the voting process. If the voter agrees with the ballot presented, than they can either press the continue button or speak the command to confirm the current view moving on to the second and final confirmation screen. If they do not agree then they

can return to a previous office and modify their vote. The second and final confirmation screen presents the ballot once again to the voter; the voter again verifies their ballot one last time before the ballot is cast and counted. The voter can still change their vote at this time. Once the voter is satisfied and agrees with the ballot, the voter can use the touch screen or speech recognizer to confirm their ballot. After the second confirmation the ballot is recorded and the user is presented with a summary of their ballot. The purpose of the summary page is for auditing and to show the voter that their vote has been recorded. This ballot summary screen has a unique identifier to help with the auditing process. The white background distinguishes the summary page from all previous pages. This makes it easier to find and read during an audit of the election.

Although the user interface is designed to accommodate for various impairments there are some impairments that the visual interface is not ideal. This is where the multimodal aspect of Prime III is needed. The multimodality of Prime III allows voters to hear, as well as, see the candidate names while they vote for a candidate and also verify their votes through the touch-screen or speech. As mentioned previously voters can interact with Prime III by using the touch-screen monitor, additionally voters can use the automatic speech recognizer (ASR) and text to speech (TTS) engine.

Voters who use the voice user interface will put on the headset with microphone and speak a command to start the voting system. The voting system will take the voter to the first office. The TTS engine speaks the ballot options currently displayed on the screen. Each candidate name is spoken followed by a 1.5 second pause. The voter can at this time issue one of the following commands “vote”, “go back”, “continue”, “clear selection” or they can blow into the microphone. By speaking vote the voter will cast a vote for the last spoken candidate, go back goes to the previous office, “clear selection”, clears the current choice. If the voter is unable to speak they can also blow into the microphone to register their selection. By using these simple commands it eliminates the potential for voter confusion and also allows the voters vote to remain confidential from eavesdroppers. An example dialogue is provided below.

- You are voting for <Office Name>
- This is <Current Office number> of <Total number of Office> Ballots
- There are 5 options. You can select only candidates
- To vote for <candidate name> say vote <beep>
- To continue say Continue <beep>
- To go back say back <beep>
- To clear the selection say clear <beep>

Prime III was designed to overcome the shortcomings of the current accessibility developments in electronic voting systems. The multimodal approach of Prime III allows the voter to speak their response which may be more natural for them. Additionally, Prime III takes into account the way races are displayed on the screen. Since paper ballots do not translate directly to the screen, special design considerations are needed. Where other systems simply scan the paper ballot, Prime III has one race per screen in a single column. The single race per screen removes the potential for under votes due to voter confusion. It also allows the visually impaired voter to navigate easily using their limited sight or with the aid of the audio. This multimodal aspect

gives another valuable tool for the seeing and physically impaired voter that was not available before. In contrast with other implementations, Prime III enables voters to cast their ballots hands free using the speech interface. As such, voters with limited use of their hands can independently cast their ballots.

2.1 Prime III Security

With any voting system it is necessary to touch upon the security aspect of the system. The security of a voting system has profound impact on how a voter will interact with the system. Prime III implements both hardware and software security measures in order to provide a secure and open voting system. Prime III is designed to offer an open environment that promotes security and transparency. Voters are given access to touch screen monitors and/or headsets in the booth while the Prime III system itself is secured in a separate yet viewable area of the precinct. Removing the voting machines and storage devices from the voting booths offers an open environment in which continuous oversight of every machine throughout the entire election is possible. Also note that the voting machines are running off of bootable DVDs, limiting the possibility of viruses or external changes to the Prime III code.

In order to deliver a verifiable audit trail for an election, Prime III uses video surveillance to provide a Voter-Verifiable Video Audit Trail (VVVAT). An external video recorder is connected in-line between the voting machine and the touch screen monitor to record everything that is shown and spoken to the voter throughout the election. The recorders captures all on-screen interactions, both through touch and voice, to ensure that everything the voter sees is recorded and can be reviewed after the election to verify the results. The voter is never recorded on the video ensuring that voter privacy is maintained. The video recorder acts as a third-party observer for each vote cast, ensuring that a separate record of each casted vote is available to compare against the voting machines' count to ensure an accurate result. For more information on the security of Prime III see [8].

3 Experiment Study

Building on the lessons learned from the first study with the Alabama Institute for Deaf and Blind [9] a second study was designed to test a number of modification done to Prime III in response to feedback from the first study.

3.1 Participants

There were 77 participants (55% female, 45% male, mean age = 45.7, SD = 16.81) from the Alabama Institute for the Deaf and Blind participated in this study. All participants volunteered to be a part of this study.

3.2 Materials

All participants were required to fill out a pre and post survey. In circumstances where the participant had a seeing impairment a proctor was allowed to read to the participant

each question in the survey and mark their answer. Pre survey questionnaires collected data on participants such as age, gender, years of computer use, computer literacy, internet comfort and computer trustworthiness. These numbers are based on a 5 point Likert scale with 1 being strongly agree and 5 being strongly disagree. On average, the pre-survey showed that participants were not particularly trustworthy of computers with information (average: 3.12, standard deviation: 1.52). As we discuss later, participants were comfortable and trusted Prime III with their vote. On average, the participants used computers for about a decade (AVG: 10.6 years, SD: 7.77), with the majority considering themselves to be computer literate (AVG: 1.76, SD: 1.32). Table 1 summarizes the pre survey information.

Table 1. Pre-survey using a 5 point Likert scale 1 strongly agree - 5 strongly disagree

Pre Survey	AVG	SD
Participant age	45.7	16.81
Years of computer use	10.6	7.77
Computer literate	1.76	1.32
Good with computers	1.91	1.37
Trust computers for online shopping	2.37	1.41
Comfortable with computers to pay bills	2.68	1.51

The pre survey also collected disability information. This information showed that 82% of the participants had a disability. Table 2 shows a breakdown of the impairments.

Table 2. Impairment Statistics

	Number	%
No impairment	14	18.18%
Visually impaired	62	81%
Hearing impaired	3	1.39%

A post survey was also given to the participants upon completion of the study. The post survey captured the participants voting experience. Specifically the post survey was composed of two sets of questions – the majority requiring answers on a Likert scale, and a separate set of open answer questions. The questions that required an answer on a Likert scale were separated into two categories general, and feature specific. The post survey findings are further discussed in the results section.

3.3 Apparatus

Four laptop were used, three Dells and one HP. Each laptop was loaded with Windows XP, Java Runtime Environment (JRE), Sphinx recognition engine and FreeTTS.

The visual interface was rendered through the use of Java Swing, the Sphinx recognition engine was used to recognize the voters spoken input and FreeTTS was used to generate the text to speech (TTS) for voters using the headset.

Four Elo touch screen monitors where used. These monitors provide a means for the voter to interact with the Prime III voting system. The resolution on the touch screens where set at 800X600 for optimal viewing. Participants who used the touch screen sat approximately 2.5 feet from the interface.

Four Logitech noise cancelling headsets where also used. The Logitech headset has a built in noise cancelling microphone. Additionally ear covers where used as a means of keeping the headset sanitized.

One Samsung digital video recorder was used in this study. The digital recorder is used as an independent device that records the video and sound produced by the Prime III system. This information is used for auditing purposes. Each recorder is capable of recording up to four Prime III systems.

3.4 Procedure

- *Pre-Study:* Participants completed the pre survey questionnaire with assistance from a Prime III member if necessary.
- *Study:* Upon completion of the consent form and pre survey the participant was led to an available Prime III voting system. At this point the participant no longer received direction from the administrators. The participant would choose to use the headset if necessary or just the touch screen. Each participant was allowed to vote on any office or skip any office and vote for any candidate that they chose.
- *Post-Study:* Upon completion of the experiment participants filled out a post survey questionnaire. The participants were also debriefed and thanked for their participation.

4 Results

The following are the results from the post survey describing the participant's opinions of the Prime III system. The first set of questions is in regards to the Prime III interface using either speech or touch-screen. The results of the questions asked in the feature specific category of the questionnaire follow. These results were gathered to evaluate the use of the individual touch and speech features. The results were collected to determine the difficulty level of error recovery and ballot casting, and the ability to use the system intuitively. Table 3 and 4 show the feature specific question and their analysis for the touch and speech feature respectively.

Because 81% of the participants were visually impaired, the speech specific questions were the most relevant and applicable questions for this particular study. These results are essential to the development of the Prime III system. The following trends are the results of analyzing the information gathered from the speech feature specific questions. Overall the participants found Prime III easy to use and would use the system again see table 5.

Table 3. Touch Feature 5 point Likert scale (1 Strongly Agree - 5 Strongly Disagree)

Post Survey Touch Feature Specific	AVG	SD
Touch feature was easy to use	1.5	.70
Easy to cast my vote	1.68	.95
Easy to correct mistakes	1.70	.73
Was able to successfully complete the task	1.35	.49

Table 4. Speech Feature 5 point Likert scale (1 Strongly Agree - 5 Strongly Disagree)

Post Survey Speech Feature Specific	AVG	SD
Easy to cast my vote	2.15	1.17
I knew what to say during the task	1.81	0.84
Easy to correct mistakes	2.31	1.25
Was able to successfully complete the task	2.18	1.25
Easy to understand the system's instruction	2.14	1.12
Easy to speak to the system	1.88	1.03

Table 5. Prime III Overall 5 point Likert scale (1 Strongly Agree – 5 Strongly Disagree)

Prime III Overall	AVG	SD
Easy to use	1.88	.97
Would use again	1.84	1.00

Finally, we made the following observations:

- Although the average participant gave the sound of the system a high rating, many commented on the sound in the open answer section of the survey. They stated that they would like to be able to adjust the speed of the system's speech.
- Many participants had trouble adjusting the sound of the speech using the headset provided.
- A more realistic voice is desired. Some participants found it somewhat of a challenge to understand the synthesized speech of the system.

5 Conclusion

The results suggest that the majority of participants were satisfied using Prime III, 57% of the participants choosing a 1 or 2 on the Likert scale. The participants rated Prime III as very usable, and enjoyed the interface, whether it is touch or speech. Although the participants rated that they did not trust computers, the average participant trusted Prime III and would use the system again. The participants also felt that Prime III would be easy to use for people who were not computer savvy.

Although voters were given the option to interact with the system using a combination of the touch and speech features, or to use each feature independently, since most of the participants were blind or visually impaired, they relied on using the speech option. Using this option, participants felt that it was easy to speak to the system, and that it was easy to understand the system's instructions.

Those participants, who used the touch feature, the speech feature, or both, felt that the Prime III system efficiently helped them understand what to say or do to vote. If they made mistakes, the participants felt that the Prime III system was reliable in allowing them to correct and cast their votes.

Overall, the participants in this study were satisfied with the Prime III system. The participants felt comfortable using the system, and trusted it to successfully cast their votes. Having disabilities, the participants indicated that they needed a way to vote independently which Prime III provides.

Although the results are promising further research is necessary to examine voter intent. It is important to understand if the voter's intent is captured accurately.

Another goal is to develop a Virtual Reality (VR) version of Prime III. One of the drawbacks of the current system is the amount of real estate space necessary for the hardware, wiring, and screens. The use of a VR voting system will allow voters the ability to vote anywhere in the precinct and still maintain confidentiality.

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