RICE UNIVERSITY

A Usability and Real World Perspective on Accessible Voting

by

Gillian E. Piner

A THESIS SUBMITTED
IN PARTIAL FULFILLMENT OF THE
REQUIREMENTS FOR THE DEGREE

Master of Arts

APPROVED, THESIS COMMITTEE

Michael D. Byrne, Ph. D.
Associate Professor, Psychology

Philip T. Kortum, Ph. D.
Faculty Fellow, Psychology

David M. Lane, Ph. D.
Associate Professor, Psychology

HOUSTON, TEXAS
SEPTEMBER 2011

ABSTRACT

A Usability and Real World Perspective on Accessible Voting

by

Gillian E. Piner

The HAVA (Help America Vote Act) mandated that all polling places provide privacy and independence to voters. DREs (Direct-Recording Electronic voting systems) have been assumed to be the solution to providing accessible voting, but there is reason to believe extant systems do not adequately serve this goal (Runyan, 2007). Study 1, a mock election, is a first step in addressing the lack of existing data on the usability of accessible voting methods. In comparison with sighted users, blind users took five times longer to vote. Both populations showed similar error rates and types, and reported similarly high satisfaction with the usability of paper ballots. Study 2, a survey, provides the opinions and recommendations of 202 legally blind voters. Data-based recommendations for auditory modes of voting systems include adjustable speed and volume, using male text-to-speech synthesized voices, and allowing for flexible navigation. This research provides a comparison point and guidelines for future studies of accessibility solutions.

Acknowledgements

It is with immense gratitude that I acknowledge the guidance of my advisor, Dr. Michael D. Byrne, and thank him for introducing me to this field of research and for all that he has taught me. I also wish to thank my committee members, Dr. Phillip T. Kortum and Dr. David L. Lane, for their advice and feedback. Many thanks to the individuals who participated in this research and were willing to share their time, experiences, and passion for this cause with me. Finally, this work wouldn't have been possible without my family and friends and their untiring support and encouragement.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Introduction

Creating a usable voting machine is a challenge that has not been well met by existing systems. This problem is made even more difficult when considering populations with special needs. With 1.3 million legally blind individuals in the United States (and 20% of the population living with one or more disabilities), this represents a substantial segment of the voting eligible population (U.S. Census Bureau, 2005). The act of voting in an election can be a complicated and time-consuming process for anyone. It involves getting to the polling place, signing in, understanding and responding to any directions given by a poll worker, comprehending the voting technology and how to use it (be it paper ballot, lever machine, computerized voting machine, etc), making selections on a ballot, possibly verifying those selections, and casting the ballot. For blind and sight-impaired members of the community, the complications that may arise during the voting process are magnified and new obstacles are often introduced. This is especially true when election administrators and voting equipment designers do not have a complete understanding of the processes someone with a disability must go through in order to vote. While there are many sources of guidelines for the design of accessible systems, there is scant empirical literature that specifically addresses the needs of visually impaired voters. Field observations can be a useful source of data in this regard, but it's also necessary to get a clearer sense of what the broader experiences are for the visually impaired as they vote.

The Help America Vote Act (HAVA) mandates that all polling places have an accessible method of voting available for those wishing to vote in federal elections (United States Government, 2002). These rights extend to two crucial aspects of voting:

privacy and independence. Voter privacy encompasses a person's right to anonymity during the election process, including the transmission, receipt, and processing of ballots. Voter independence means that an individual with disabilities has the same opportunity for access and participation as others, without requiring the assistance of another party.

On the surface, DREs (Direct-Recording Electronic voting systems) appear to have great potential to provide comprehensive access to people with disabilities. While DREs have almost certainly improved the situation for voters with a wide variety of disabilities, current implementations are often far from the ideal in terms of accessibility (Runyan, 2007). Audio instructions are frequently long and tedious, and interaction with the voting system requires voters to listen to repetitive selections with no way to quickly navigate through sections of the ballot that they are not interested in. The physical buttons and keypads used for tactile interaction can be poorly designed (such as having similar keys that are not easily distinguished by the button's shape or some other marker or keys that are so close together that they are often mistakenly pressed) and poorly labeled (Cross et al., 2009). One difficulty in usable design is the lack of systematically collected, publicly available data on usability of voting systems for different groups. A goal of this research is to extend the voter usability literature to the specific demographic of legally blind users. "Legally blind" is defined as having "central visual acuity of 20/200 or less in the better eye with the use of a correcting lens" and/or having "the widest diameter of the visual field subtend an angle no greater than 20 degrees" (National Federation of the Blind, 1986).

"Universal access" is an approach to usability that is targeted towards providing equal access to computer-based applications for users with disabilities. It aims to consider human diversity and provide technology without excluding users, while at the same time improving the quality of products for use by the general population (Stephanidis, 2009). Universal access directs that there should be a study of both human characteristics and requirements in the development process.

The goal of the two studies reported here is to understand the experience of voting for blind individuals and identify areas that can and should be improved upon in future designs of voting technology. Study 1 utilized a non-electronic, tactile paper ballot called Vote-PAD (Voting-on-Paper Assistive Device) that 21 people voted on in a mock election. Vote-PAD uses a specially designed plastic sleeve that fits over a standard paper ballot. Holes in the sleeve correspond to where voters can make a mark, and audio instructions guide users to the raised bumps next to each selection and tell them who or what each marker represents. The holes correspond with the ovals on the ballot, so voters can mark their selection with a pen or pencil without going outside of the oval. Afterwards, voters can run a light-sensing wand over the selections to verify their choices. Voting time, errors, and user satisfaction were measured. Study 2 was a 52 question survey designed to obtain information about blind voters' demographics (age, gender, education), voting history (number of previous elections, absentee and early voting tendencies), polling place interactions (types of machines used, attitude towards poll workers, obstacles faced at the polls), and desired changes in current voting technology (preferences for audio, visual, and Braille settings). The in-depth survey of voting habits and desired changes to voting systems attempted to both understand the unique challenges facing this population and provide future direction for the design of accessible voting. The combination of information from both Study 1 and 2 provided a universal framework from which to consider future research and to ultimately assist in the design a new, accessible user interface informed by the data collected.

When designing a user interface, consideration must be made for individuals who may not be able to interact with a technology in the same way that the general population does. If a user is unable to interact with a device or an environment, there are three things that may be done to alter this. First would be to change the individual, through the likes of medicine or surgery, so that they can use the world as it is. Second would be to focus on a single, individual product and change it in a way to make it accessible to the specific user considered here. The final option would be to change the world, so that the technologies and interfaces that exist there are easier for people to use regardless of the details of their disabilities (Vanderheiden, 2009). Ideally, utilizing the information from Studies 1 and 2 will promote change in the world of voting by encouraging improved design strategies for providing access to visually impaired and blind individuals.

Previous research on voting has focused mainly on the effect of voting technology on election outcomes. Nichols and Strizek (2005) examined how ballot roll off (the tendency for races higher on the ballot to receive more votes than those races located lower on the ballot) could be influenced by a change in the technology. Moving from non-electronic to electronic voting methods noticeably increased the rate of voter participation in these lower electoral races. Nichols and Strizek hypothesize that this was because undervoted races were made more salient on the electronic voting machines through the use of blinking lights, and some voters may have felt obligated to resolve these contests before casting their ballot. The issues raised by the voting problems in the 2000 presidential election in Florida spurred several papers that looked at the shortcomings of the specific ballots used there. Mebane (2004) focused on the lack of a system to caution voters that over votes (making too many marks on a ballot, and thus voiding the ballot) were present on their ballots. Wand et al. (2004) assessed other systematic voting errors that occurred on certain ballot types (such as the now-infamous "butterfly" ballots) that could cause either invalid ballots or ballots that did not correctly represent the voter's intention.

Perhaps the most significant impediment to a fair and just democratic process, and the biggest obstacle that voting technology needs to overcome, is that the ability to vote must generalize to the extremely diverse population of all Americans over eighteen years of age. This is a much broader target population than virtually any other human-machine system. In particular, voters with disabilities make up a sizable portion of this population. The Americans with Disabilities Act (United States Government, 1990) defines a disability as "a physical or mental impairment that substantially limits one or more major life activities." Despite the implementation of HAVA, disabled voters continue to face difficulties during the election process and are under-represented. Among the voting eligible population in the 2008 presidential election only 56.8% of people with visual impairments voted, compared to 64.5% of people without disabilities (Schur and Kruse, 2008). According to the U.S. Census Bureau Americans with Disabilities report (2005), 19% of the US population lives with one or more disabilities. A fifth of those Americans with disabilities (more than eight million people) have been unable to vote in presidential or congressional elections due to barriers at or getting to the polls (National Organization on Disability, 2004).

It is clear that this legislation has already made an impact on the voting experience for many. One emphasis of the end-user survey in Study 2 was to document experiences such as this one, from one respondent: "I would like to say that the first time I voted completely on my own with an accessible voting machine, it was such a liberating experience that I cried. I was so elated that everyone in the polling place applauded." The goal of better understanding the needs and preferences of this population is to provide this experience to even more visually impaired voters.

Manufacturers of voting systems have been tasked with making changes to provide independent and private voting. Current manufacturers claim that their systems allow everyone to vote without assistance. Hart InterCivic (2010), the company that manufactures the eSlate electronic voting system, explicitly states on their website "The eSlate enables private, independent voting for persons with disabilities." However, DREs seem to have inherent shortcomings, many of which are outlined by Cross et al. (2009). The eSlate has buttons that are located close together and this could cause accidental selection of undesired keys. There are potentially confusing labels on the eSlate. It provides voters with both a "select" dial and an "enter" button. The AccuVote-TSX, an optical scan voting system that reads and tabulates marked paper ballots, requires a voter to insert an identification card that they receive from a poll worker. All voters are expected to locate the slot and correctly insert the card before they can even begin the process of voting. The AVC Edge is a touch-screen electronic voting system for most voters, but provides Braille buttons for the visually impaired. To voters that are less knowledgeable about physical interfaces, these small things can provide insurmountable challenges during the process of voting. Additionally, because fewer than 10% of legally blind Americans are Braille readers, it is critical that the audio interface be made a priority when developing accessible systems, rather than relying on a misguided notion that everyone with visual impairments is also a Braille reader (National Federation of the Blind Jernigan Institute, 2009). An audio interface allows the highest level of accessibility across individuals with some form of visual impairment. An audio-only interface certainly disenfranchises voters with co-occurring visual and hearing impairments. But unlike instructions and interactions relayed in Braille, audio requires no specialized skills.

A majority of states utilize several levels of testing that are designed to insure that a voting machine adheres to standards for accuracy and reliability (Mulligan & Hall, 2004). The EAC (Election Assistance Commission) provides voluntary testing and certification of voting systems for the states (United States Election Assistance Commission, 2007). The manufactures first submit their software program and coding to an independent testing authority, to be tested against the VVSG (Voluntary Voting System Guidelines). States may also require that voting systems undergo additional testing before the equipment is certified for use in a given state. But the final burden rests on the individual jurisdictions, whose election authorities are charged with determining if "the equipment meets the needs of the citizens under their jurisdiction" (Citizen Advocacy Center, 2004). Many governmental bodies do not have the information, understanding, or resources to provide the thorough and rigorous tests that are needed to establish whether a system is both secure and usable. And while product testing with a few people with disabilities by the manufacturer is an important step, it does not come close to providing the understanding that is made available through a survey of the specific population.

Understanding the voting process and how to better advocate for equal rights for the visually impaired is a topic that has received a lot of attention from the NFB (National Federation of the Blind), the country's largest membership organization of blind people (NFB, n.d.). Elections give people opportunities to voice their opinions about elected officials and legislation relating to disability benefits, employment equality, health benefits, and many more highly relevant issues for visually impaired citizens. It has been difficult for blind voters to participate in elections privately and independently because very little information exists on the best way to provide these. A systematic survey of the blind voting population is one way to obtain a better understanding. The NFB's Jernigan Institute conducted a telephone survey of 557 blind individuals of voting age, representing all 50 states, following the November 4, 2008 national election (Hollander Cohen & McBride Marketing Research, 2008). While 90% of the households surveyed had voted in the 2008 election only 51% were able to do so independently. Out of those that voted in a location that offered an accessible voting machine, 86% were able to vote secretly. This largely successful percentage indicates that accessible DREs are good, and are probably the best option currently available for providing universal access to voting. It is clear from the missing 14% and other studies on potential issues with DREs (see Runyan, 2007 and Cross et al., 2009) that these systems are by no means perfect. Extant commercial systems are an important first step, but there is still a great deal that can be done to improve the user interface and voting experience as a whole.

Some items from the NFB's 2008 survey overlap with Study 2's inquiries, including what types of machines were used and voter success and confidence in those voting methods. In addition, detailed questions regarding polling locations, transportation, and poll worker interactions were included. Examining both the survey of voters in Study 2, in conjunction with a large survey of the 2008 national election, can provide a clearer picture of the needs of blind users. Taking lessons from real-world interactions with voting machines and other accessible technology and integrating the feedback will inform a better, more usable design for a DRE user interface.

Considerable modifications are required to make existing voting technologies accessible to specific populations of disabled voters, especially those with visual disabilities. These range from purely audio instructions, inputs, and feedback to tactile and Braille interfaces to magnification and large print materials. Because of the unique alterations that need to be made and the large portion of the population that is affected, Study 2 study focuses on measuring accessible and usable voting among legally blind individuals.

HAVA strongly encourages the implementation of the newer, computerized technology, DREs (Runyan, 2007). Although DREs have been seen as a solution to many of the current problems existing in the voting world, laboratory studies have found that upwards of 10% of voters still have significant concerns about the systems' ease of use, their ability to change votes, and the correct recording of their intended votes (Bederson, Lee, Sherman, Hermson, & Niemi, 2003). DREs are sometimes considered by election officials a panacea for all existing accessibility, usability, and security problems. However, very little data exist which permits a quantifiable comparison of DREs to the older, traditional voting systems (paper ballots, lever machines, and punch cards) that they would be replacing.

A series of several laboratory experiments has attempted to address this limitation and provide the groundwork for improving voting technology in ways that can be studied and quantified (Everett et al., 2008, Byrne et al., 2007; Everett et al., 2006; Greene et al., 2006). The National Institute of Standards and Technology's (NIST) recommended solution to measuring the usability of voting systems is through the use of the International Organization for Standardization's (ISO) usability metrics: effectiveness, efficiency and satisfaction (Laskowski, 2004). Effectiveness is evaluated by how well voting methods represent a user's intent, and can be measured by error rates. This is the essence of voting: are people's ballots truly representing the candidate they want to vote for, and if not, what kinds of errors are made? Efficiency is captured in the amount of time it takes a user to vote. This is important because voting is a voluntary activity and takes place over a limited period of time during which many people must be accommodated. And finally, a subjective measure of overall user satisfaction provides insight into people's personal preferences of different voting systems.

Studies by Everett et al., 2008, Byrne et al., 2007, Everett et al., 2006, and Greene et al., 2006 have evaluated the usability of paper ballots, lever machines, and punch cards. Overall, voters (both college undergraduate students and a more representative sample of the general population) preferred paper ballots to the other two traditional voting methods. The many benefits of paper ballots include voters' general experience of interacting with paper, a direct mapping of actions onto candidates, and a simpler configuration. The major limitation of paper ballots is their inaccessibility to those with both visual and physical impairments. However, recent innovations in voting technology have produced tactical ballot-marking aids, which allow people with a wide range of disabilities the opportunity to vote independently and privately on paper ballots (Runyan, 2007). Figure 1 presents several examples of tactile ballots.

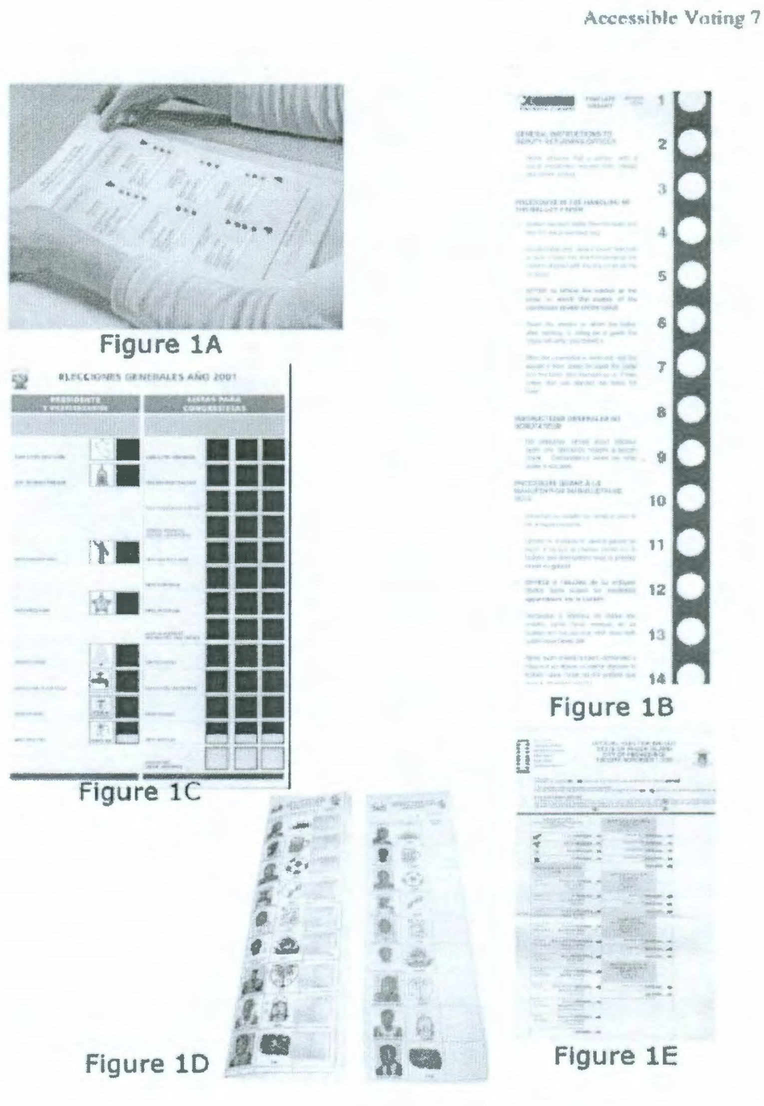

Figure 1. Examples of tactile ballots. (a) Vote-PAD (b) Braille and tactile ballots being used by the state of Rhode Island, (c) Peru (d) Republic of Sierra Leone (e) Canada.

There is a dearth of existing information on the usability of tactile ballots by blind voters, either from laboratory experiments or real-world voter experience. To determine the best course of action for implementing accessible voting systems, a comparison needs to be made between more traditional voting systems and the newer, electronic voting systems. In the 2007 top-to-bottom review of voting systems conducted by California, the human-factors design weaknesses that make certain DRE systems too complex were highlighted. "The setup of these machines in audio access mode is still too complicated for the average poll worker, marking and reviewing the ballot is too complex and takes a very long time for the audio voter, the physical privacy shielding is much worse than it used to be with punch-card systems, and audio voters do not have any way of verifying the paper audit trail privately or otherwise" (Runyan, 2007). Vote-PAD is a non-electronic system that still offers multiple interaction modalities (visual through large print guides, auditory through audio guides, and tactile through Braille guides) that can be used separately or combined in whatever manner is needed by the voter. In addition, Vote-PAD's utilization of paper ballots and a verification wand makes it the only voting method that truly allows for accessible verification of the paper record, an action that is necessary to guarantee the reliability and security of an individual's ballot (Runyan, 2007). NIST states that multiple modalities are often insufficient; "Once the barriers to access are removed by adding redundancy, a second condition must be satisfied – the product must be usable by these populations" (Laskowski, Autry, Cugini, Killam, & Yen, 2004). Study 1's purpose is to compare the usability of a tactile paper ballot by blind voters to the performance of sighted voters on an identical paper ballot. Study 2 seeks to expand on these results in a survey of blind voters that targets suspected areas of interest where this group of voters will differ from the general population in ways that need to be understood and addressed by the voting industry.

Study 1

Measuring time, error rates, and user satisfaction in a mock election using Vote-PAD serves as a benchmark for accessibility. Any future system that intends to address the needs of the visually impaired should have to show that it could perform at least as well on these three baseline measures. Naturally, the primary voting technology of interest for future research is the DRE. The development and testing of DRE using an auditory interface with blind voters will be essential to understanding the strengths and limitations of the platforms currently deployed in many polling places. Only after comparisons can be made between DREs and other technologies can a viable course of action for providing equal voting rights to the entire population be determined.

Method, Study 1

Subjects

18 blind subjects were recruited from two sources. Some were affiliated with Rice University, either as students, alumni, or faculty. Others were from the National Federation of the Blind's Texas state convention. Subjects were paid for their time. All subjects were fluent in English and legally blind (with 7 retaining some form of residual vision). Ages ranged from 18-62 years, with a mean age of 35.3 (SD = 13.4 years). On average, subjects had voted in 6 national elections (SD=5.6), ranging from zero to 20, and had voted in an average of 9.2 non-national elections (SD=5.36), ranging from zero to 35.

9 females and 9 males participated.

Data were also collected using blindfolded subjects. Blindfolded subjects were not, and were not intended to be, an analog for blind individuals. In some sense, they represented a worst-case scenario that an accessible voting system might have to deal with: a person who has recently lost their eyesight and has little to no experience using assistive technologies. This is a very real possibility, as the World Health Organization reports that age-related macular degeneration (AMD) accounts for 50% of the causes of blindness in the United States (Resnikoff S, Pascolini D, Etya'ale D, et al., 2004). In another sense these blindfolded subjects were college students, and so represent the best-case scenario because they have not experienced any of the effects of aging and slowing on cognitive performance. Measuring the degradation in their performance and satisfaction demonstrates how this voting system may be ill equipped to handle the challenges of a newly blind individual.

The 6 blindfolded subjects for this study were Rice University undergraduates who received credit towards a course requirement. Ages ranged from 18-24 years, with a mean age of 19.8 years (*SD*=2.3). On average, subjects had voted in 1 national elections (*SD*=1.55), ranging from 0 to 4, and had voted in an average of 5 non-national elections (*SD*=7.48), ranging from zero to 20. 3 females and 3 males participated.

The 54 sighted subjects used in this comparison are from data previously collected and published in a similar experiment on voting by Everett et al. (2008).

Apparatus

Vote-PAD, the voting method addressed in this study, is a tactile ballot sleeve voting system. Vote-PAD consists of front and back opaque covers, with an inner transparent sleeve that holds the actual ballot (Figure 2). The ballot is inserted into the transparent sleeve, which has holes that correspond to the size and location of the "bubbles" on the ballot. These holes allow for voters to mark the ballot for the desired candidate with a pen or pencil, while preventing any stray marks. Raised tactile markers inform users of the overall ballot layout. Triangular markers are placed at the top of each column, pointing down, and the bottom of each column, pointing up. Aligned in each column are a series of raised dots, located to the left of each cutout. These markers are designed to aid with navigating the ballot. Audio and Braille instructions interpret the raised dots and let the voter know which holes correspond to specific candidates.

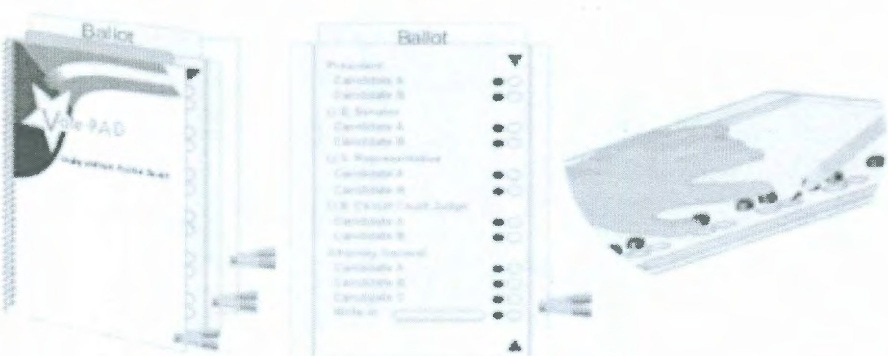

Figure 2. Vote-PAD tactile ballot.

Audio instructions were created with the text-to-speech (TTS) program Natural Reader, using the NeoSpeech voice "Kate" set to speed 2. Audio instructions were provided to subjects on cassette tape. Subjects had full control of the cassette tape player, and were informed of the player's tactile buttons (play, stop, pause, fast forward, and rewind) and the location and operation of the volume control. The play button, which was particularly difficult to find because it was centered in the middle of a section of buttons, was given a triangular tactile marker to help subjects locate it. The audio guide directed voters through the ballot using the raised tactile markers as landmarks. Each contest consisted of the reading of the candidates' names, the spelling of the candidates' last names, and the candidates' political parties. The candidates' names and parties were then quickly repeated, before moving on to the next contest. For example, the audio transcript for voting for the Commissioner of General Land Office was:

In the middle column on the front of the ballot, there are 8 contests. The top contest is for Commissioner of General Land Office, a State office. There are two candidates. Vote for only one. The top hole is a vote for: Sam Saddler, S-a-d-d-l-e-r, Republican party. The bottom hole is for Elise Ellzey, E-l-l-z-e-y, Democratic party. Again. Top hole: Sam Saddler, Republican party. Bottom hole: Elise Ellzey, Democratic party.

Braille instructions used the same text as the audio instruction transcript, except that the last names were not explicitly spelled out.

Subjects were given the option to review their ballot. A light sensing verification wand provided tactile feedback of how the voter had marked the ballot (Figure 3). The verification wand is designed to vibrate and hum when it senses a mark, and remain still when it does not. Subjects using the audio interface played the second section of the audio tape (a verification section that quickly reviewed each contest and the candidates in that contest once) while touching the verification wand to each marking location to determine the presence or absence of a mark. Subjects using the Braille interface were able to verify their votes immediately after marking each contest, or could go back at the end of the process and re-read the Braille guide in order to verify all of their votes at once. If the subjects determined that they had made an error or wanted to change their vote, they notified the experimenter who noted the change on their ballot.

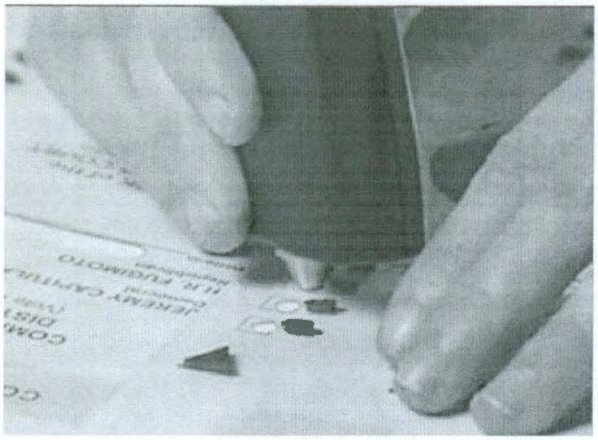

Figure 3. Light sensing verification wand.

Design

This experiment was a 3 x 2 x 4 between-subjects design. The 3-level variable was visual condition. Voters were either blind subjects voting on Vote-PAD, blindfolded subjects voting on Vote-PAD, or sighted subjects voting on a standard bubble ballot. The 2-level variable was information condition. Blind voters' information condition was dependent on the voting method they chose. Those voting with audio were in the *directed* condition, and received verbal prompts that told them whom to vote for. Those voting with Braille were in the *undirected* condition, and received a voter's guide that allowed them to make their own selections. Due to a limited number of subjects, only one information condition was used for each voting method. All blindfolded voters used the audio interface. Sighted voters were randomly assigned to be in one of the two conditions. The 4-level variable was education, a self-report measure that consisted of four categories: did not complete high school, high school diploma or GED, some college or Associate's degree, and Bachelor's degree or higher. Table 1 shows the frequency for each category; two sighted subjects did not report their level of education.

Table 1

Frequency of education level by visual condition

	Sighted	Blind	Blindfolded	General Population
Did not complete high school	7.4% (4)	--	--	13.4%
High school	9.3% (5)	22.2% (4)	--	31.2%
Some college	35.2% (19)	33.3% (6)	100.0% (6)	28.3%
Bachelor's degree	44.4% (24)	44.4% (8)	--	27.1%

Both sighted and blind subjects shared a similar background in both education and voting (Table 1). Table 1 contains information about the educational background of the general population of voters from the 2008 national election (U.S. Census Bureau, 2010). Both sighted and blind subjects also shared a similar background in voting history and unsurprisingly the younger, blindfolded subjects had far less experience voting (Table 2).

Table 2

Average number of elections in previous voting experience

	Sighted	Blind	Blindfolded
National Elections	7	6	1
Other Elections	8	9	5
Total Elections	15	15	6

Subjects were self-selected into an information condition based on their ability to read Braille. Those who chose a Braille interface were in the undirected condition. This was done out of necessity to keep the experiment at a reasonable length. The voter guide encompasses 22 single-spaced pages printed in font size 10. An audio version of the voter guide would be extremely long. In addition, subjects listening to a cassette tape would not have the ability to skim sections or easily skip to the contest they were most interested in, in the way that both the sighted users in previous studies and Braille readers in the current study were able to. Blind subjects were asked to self-report their proficiency using Braille on a scale of 1-10, with 1 representing "I can't read it at all" and 10 representing "I'm an expert." On average, blind subjects rated themselves 7.46 ($SD = 2.5$). 5 subjects did not respond. Subjects that chose to use the audio interface (12) rated themselves as having a Braille proficiency of 7 ($SD = 2.7$). Subjects that chose to use the Braille interface (6 subjects) rated themselves more highly proficient Braille readers, with an mean of 9 ($SD = 1$).

Determining error rates was challenging. Measuring effectiveness in the directed condition was a simple task of comparing the slate (a text version of the verbal prompts that told participants what candidates to vote for) to the marked ballot (how the participants actually voted). Attempting to determine voter intent in the undirected condition was much more difficult. Everett et al. (2006) solved this problem by having their participants vote three times, on three different types of ballots. A simple majority rules criterion was established. For example, if a participant voted for Candidate A on ballots 1 and 2, but Candidate B on ballot 3, it was determined that the voter intended to vote for Candidate A, and ballot 3 would be marked as having an error. Everett et al. (2008) used a similar method for determining voter intention when using more time-intensive voting methods. In Experiment 1 of their study, participants only voted twice, making it impossible to determine voter intent if there were inconsistencies between the two ballots. However, the experimenters added a third measure of voter intent (an exit interview), that carried equal weight with the other two ballots, and allowed them to determine errors.

In the current study, an oral exit interview (simply asking the voters how they voted for each race) was administered to participants in the undirected condition. This allowed experimenters to determine that the votes on the ballot that were consistent with the exit interview correctly represented voter intent. For inconsistent votes, the exit interview was counted as the definitive measure of voter intent. Having subjects vote multiple times would have been too lengthy for a single experimental session.

Errors can be classified into three categories: overvotes, undervotes, and wrong choice errors. An overvote error occurs if a voter chooses two candidates for a race in which only a single selection is allowed. This type of overvote error is part of the standard "residual vote" rate and is available in actual elections. A different type of overvote error occurs if a voter makes a selection for a race s/he had originally intended to skip (either due to instructions in the directed information conditions, or personal preference in the undirected condition). These are referred to as extra votes. A distinction is also drawn between two types of undervotes: omissions and abstentions. An omission occurs if a voter fails to choose a candidate for a race in which s/he had intended to vote. An abstention occurs when a voter omits a race on purpose; this is not actually an error. Finally, a wrong choice error occurs when a voter makes a selection other than the one intended (Everett et al., 2008).

Materials and Procedure

Subjects who were comfortable with reading Braille and chose to vote with the Braille interface (instead of the audio interface) were placed in the undirected condition. Those in the undirected condition received a voter guide (based on guides produced by the League of Women Voters), and were instructed to use it like they would in a real election (either by reading it completely, skimming it, or not using it at all). The voter's guide was transcribed in Braille, and provided additional information about the candidates and their position on certain issues. Subjects in this condition made their own choices about what candidates and propositions to vote for.

In the directed condition, subjects using the audio interface were given verbal prompts that informed them which candidates to vote for and whether a yes or no vote was desired on the propositions. The experimenter provided these to the subjects. Subjects could pause the audiotape and ask for certain information from the slate whenever they desired it.

There were two versions of the directed condition. In the directed with no roll-off condition, subjects were instructed to vote in all 27 races on the ballot. In the directed with moderate roll-off conditions, subjects were instructed to skip several of the races and propositions. These omissions were more representative of real-world voting patterns, in which people do not vote for every race presented on the ballot.

Both the voter guide and the verbal prompts (synonymous with the slates used in sighted experiments) were identical to those used in previous studies (Byrne et al., 2007; Everett et al., 2006; Greene, 2008; Greene et al., 2006). The only difference was the modality that they were provided in (either tactilely with Braille or orally by the experimenter).

Subjects gave their informed consent and were then read instructions on how to vote using Vote-PAD based on the directions provided in Vote-PAD's Poll Worker Guide (Vote-PAD, n.d.). These instructions differed significantly depending on the type of interface (either audio or Braille) used. Subjects in the directed condition were informed about the audio prompts, and those in the undirected condition were provided with the voter guide and time to read through it, if desired. Subjects were given an opportunity to ask any questions before they began voting. Voting was timed by the experimenter, using a stopwatch. Time started as soon as the participant started reading the Braille instructions or pressed play on the audio instructions, and ended when the participant said they were finished voting. Subjects sat during the entire voting process, and were provided with ample table space to allow them to arrange all parts (ballot, tape player, instructions, voter guide, pen, verification wand, etc.) of the Vote-PAD system in any way they desired.

The paper bubble ballot used in this study was identical in content to the ballot used in previous studies. They were very similar in layout. They presented the races and propositions in the same order, but spacing was altered slightly to accommodate the tactile markers required by Vote-PAD. The spacing was such that subjects would be able to differentiate races based solely on tactile cues. The candidate names were fictional, and created by a random name generator. The ballot was based on actual optical scan ballots in use in the United States (Byrne et al., 2007).

Blindfolded subjects were blindfolded using sleep masks after reading and signing the consent form, but before beginning the experiment. All blindfolded subjects were placed in the audio condition, which proceeded in an identical manner to the blind subjects in the audio condition.

Sighted subjects voted on identical bubble ballots, but without any of the Vote-PAD materials. They were given text voter guides or text slates that listed the candidates they were required to vote for, depending on the information condition. They read all directions themselves. These votes were performed in the context of a larger experiment, so some sighted subjects had voted on these ballots one or more times using other voting methods (DREs, lever machines, etc).

After subjects completed voting on and verifying their ballot, they were provided orally with several surveys by the experimenter. Blindfolded and sighted subjects received these surveys in writing. A general survey asked demographic questions and voting experience questions (such as how many elections have you voted in). A voter guide survey (which differed slightly depending on the information condition) assessed how much a participant used (or would have used) the voter guide. The System Usability Scale (SUS), a ten item Likert scale, assessed subject's agreement or disagreement with statements about the voting method, such as "I thought the system was easy to use" (Brooke, 1996).

Results, Study 1

Errors

Error rates can first be considered on a per-race basis. There were 27 races (21 offices and 6 propositions), which meant voters had 27 opportunities to make an error. Per-race error rates were calculated by summing the total errors and dividing by the possibilities for errors. The per-race error rates are displayed in Figure 4. There were significant main effects of both visual condition, $F(2, 57) = 3.56$, $p = .035$ and education, $F(3, 57) = 2.87$, $p = .045$.

However, Subject 10 in the blind condition had errors in 10 out of the 27 races, an individual error rate of 37%. When this subject was excluded from analysis, blind subjects had a per-race error rate of 1.7% (*SD* = 3.2%), which is far more similar to the sighted subjects. With Subject 10 removed, there was also no statistically-reliable difference between error rates as a function of visual condition, information condition, or education.

Blind subjects choosing their own votes in the undirected condition made more errors (3.7%) than blind subjects in the directed condition (0.7%), although this difference was not statistically significant.

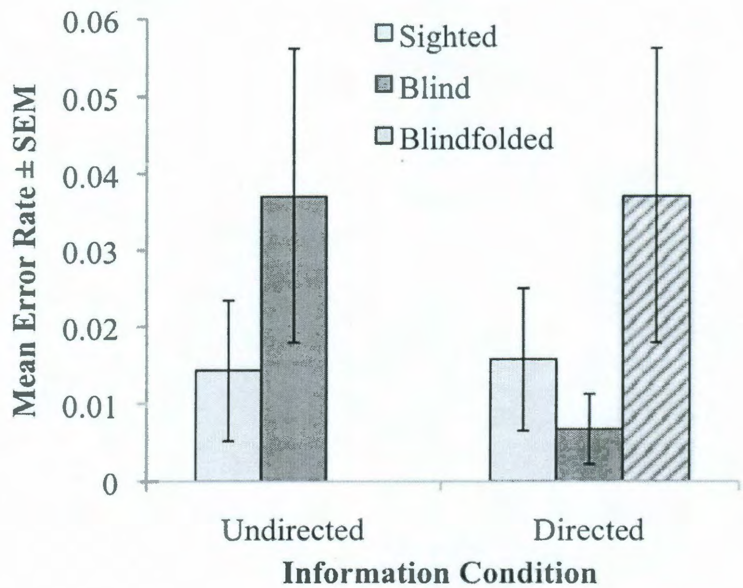

Figure 4. Per-contest error rate vs. visual condition and information condition, with subject 10's data removed.

Both sighted and blind subjects show similar patterns of errors, as seen in Figure 5. Errors were classified using a much broader taxonomy by Everett, et al. (2008), so the sighted data presented in Figure 5 is from Campbell and Byrne (2009), which used an identical ballot and experimental methodology to what was used in this experiment and the Everett, et al. (2008) paper but utilized a finer grain classification system for errors. Wrong choices were the predominant form of errors (even when Subject 10's errors—all wrong choices—were removed from the analysis). There were no cases of overvotes or extra votes among blind or sighted voters. A few subjects exhibited omissions and abstentions. Blindfolded subjects showed an entirely different pattern. They tended to have overvotes and extra votes, along with a few wrong choice errors. They exhibited no omission errors. In the blindfolded paradigm, they were given verbal prompts and told who to vote for, so abstentions were not possible.

Abstentions are not considered an error, so were not included in the graph. Sighted subjects had an abstention rate of 0.4% and blind subjects had an abstention rate of 0.6%, which was not significantly different.

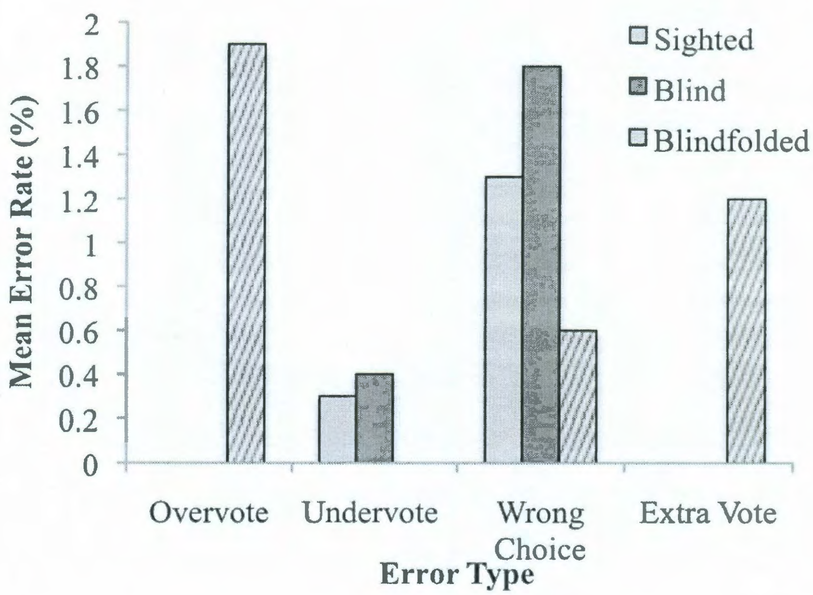

Figure 5. Error rates for different error types by visual condition, with Subject 10's data removed. Inclusion of Subject 10 would increase the blind wrong choice error rate to 3.1%.

The error rates for both the audio and Braille interface of Vote-PAD (both 3.7% when including Subject 10) were not significantly different. Error rates can also be considered on a per-ballot basis. Overall, 14.3% of ballots collected from sighted subjects contained at least one error. 33.3% of ballots collected from blind subjects contained at least one error. 50% of ballots collected from blindfolded subjects contained at least one error. Error rates by ballot were not related to information condition, though effects of both visual condition, $F(2, 57) = 2.57, p = .085$, and education, $F(3, 57) = 2.39, p = .078$, approached significance.

Ballot Completion Time

Overall ballot completion times are presented in Figure 6. As expected, there was an overall effect of visual condition on ballot completion time, with blind voters having much longer times than sighted voters, $F(2, 62) = 165.24, p < .001$. More specifically, blindfolded subjects took significantly longer than blind subjects, who took significantly longer than sighted subjects. None of the effects of information condition or education were reliable, nor were there any interactions.

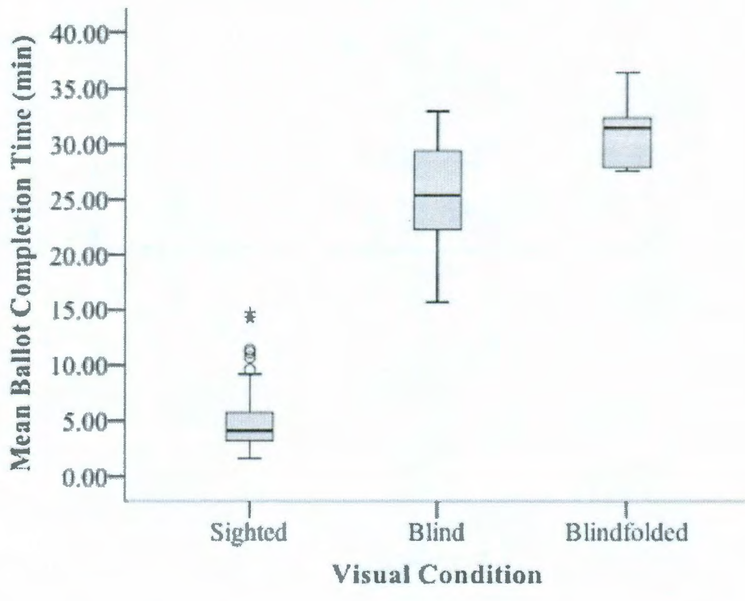

Figure 6. Mean ballot completion time by visual condition.

Both Braille and audio interfaces took similar amounts of time to complete, and were not reliably different (24.5 minutes for Braille vs. 25.5 minutes for audio).

Subjective Usability

Figure 7 depicts the mean SUS rating as a function of visual condition and information condition. Both sighted and blind voters showed a similar high rating, with blindfolded subjects rating the usability as substantially worse. Unsurprisingly, there was a significant effect of visual condition on SUS scores, $F(2, 62) = 9.28, p < .001$. Sighted and blind subjects had similar SUS scores, but blindfolded subjects' ratings were reliably lower. There were no effects of information condition or education.

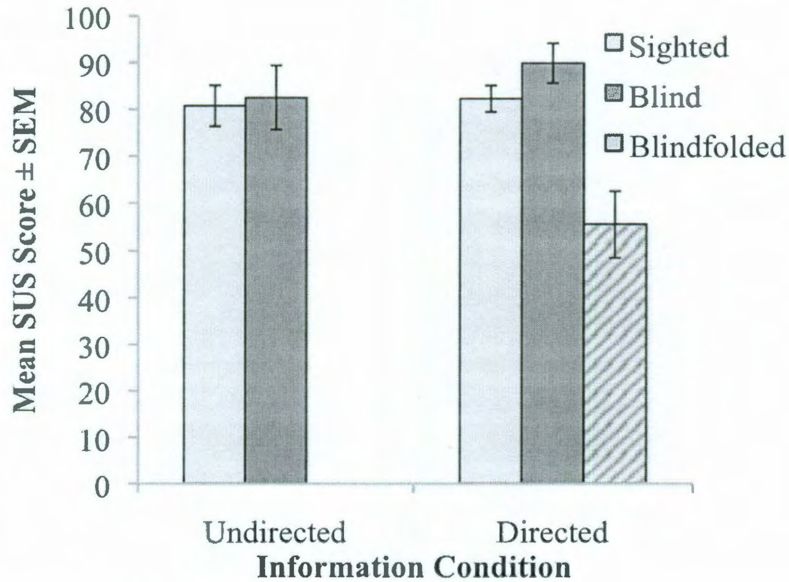

Figure 7. Subjective usability score (SUS) by voting method and information condition.

Audio interfaces received a higher subjective rating for usability. Subjects using Braille gave the method an 82.5 SUS rating and subjects using audio gave the method an 89.8 SUS rating. This difference approached significance, $F(1, 13) = 4.43, p = .055$.

Both the usability scores of Vote-PAD with blind voters and identical paper ballots with sighted voters fell into the range of the 80s. The data collected by Bangor, Kortum, and Miller (2008) allows for an assessment of the SUS number obtained in Study 1 and a better understanding of how the measurement of Vote-PAD's subjective usability fits into the larger universe of SUS scores for all types of products. Based on their findings, both paper ballots and VotePAD have passable SUS scores (above 70) and fall into the range of "better products" (by scoring in the high 70s to upper 80s). The research by Bangor, Kortum, and Miller (2008) sought to associate an adjective rating with the SUS's result of a single reference score regarding a product's usability; Vote-PAD can be labeled as obtaining an Excellent score (equivalent to a 6 on a 7 point adjective rating scale). A large benefit of the SUS is that it is "technology agnostic" which allows for comparison of usability scores across different interface technologies (e.g., visual written text and audio on a tape recorder) and will make it feasible to compare this baseline data with future voting systems.

The perceived usability of voting methods is an important topic, though not just because HAVA has made a requirement that each polling place provide private and secure voting for every voter (United States Government, 2002). It is also a topic that is important to blind individuals. Half of the blind subjects said that when they voted in an election they had been unsure if their vote was cast correctly or would be counted. Several subjects mentioned that they had been unsure if their votes were cast correctly when they were forced to have poll workers mark their choices for them. One subject mentioned that she was specifically concerned about the new security issues being introduced by electronic voting, and another subject said "When I voted electronically, I was like did that really go in?" A third subject said with the audio interface on a DRE he could cycle through the races but could not determine what he had selected. Another subject said she was worried about voting integrity after the 2000 election. A final subject said he was worried because "when you're using a machine, it separates you from the ballot, and you don't get a chance to know you submitted it." He mentioned a specific instance when he voted on a DRE but required a poll worker to help him submit his ballot. Upon leaving the polling location, the sheriff (who happened to be a candidate on the ballot during that election) was aware of what vote the subject had cast. This made an impression on him about the importance of privacy and independence when casting a vote.

Blind and sighted subjects had a similar average number of voting experiences. A further examination of the type of experiences is shown in Table 3. Some subjects had experiences with multiple methods, and several subjects had voted before they went blind.

Table 3

Blind subjects' previous voting experience

Voting Experience	Number of People
Never Voted	2
Paper Ballot w/poll worker or family assistance	7
Punch Card	2
Lever Machine	1
DRE	12
Stopped voting when they lost their vision	2

A substantial finding here is that 2 out of the 18 subjects stopped voting after they lost their vision. It is possible that a usable method that insured privacy and independence would encourage individuals like them to continue voting even after a significant life change such as losing one's vision.

In general, the high mean SUS scores and quotes from subjects indicate blind voters felt that the Vote-PAD system provided a necessary and satisfactory service. In comparison with other systems, one user spoke about Vote-PAD: "I find this much nicer than electronic ones. This focuses you on what you're doing. Electronic ones you have to go back and forth." Several felt that this system was an important step forward in assistive technology for people that might not know Braille, or might not be comfortable using it: "I like the orientation cues like 'second from the bottom' were really good, especially for a non-Braille reader, it will help get them back to their place." and "Very intuitive system, people can't stand tapes any more, but a digital system adds a level complexity. And not all people know Braille."

There were some things that multiple subjects wanted to change. A desire to make the system more compact was prevalent ("It would be nice if it were more compact, some way to integrate everything and not spread everything out."). Subjects also came up with a few more features to help people navigate and differentiate between different parts of the ballot ("Very tiny holes, I don't know if someone is elderly or someone with diabetes could vote with this." and "What's hard is finding the hole with the pen and not making other markings. Put a frame around the candidate or separate the circle [referring to the raised marker] from the hole.").

Ballot Verification

The verification wand was a piece of technology that received a strong, positive response from voters in this study. It elicited comments such as “I like the wand a lot” and “I like it, it’s very cool” [referring to the verification wand]. Subjects varied greatly in how much and how effectively they used it to verify their ballot. In order for the verification wand to work properly, it must be held straight up and down and lightly touch the paper. Although this was emphasized during the instructional phase, several subjects either held it at an angle (as one would a pen) or failed to touch the paper with it at all, causing the wand to always vibrate and respond as if they were touching a mark. Because some users were receiving false positive feedback about a mark that was not actually present, this technique may have contributed to the undervote rate.

Some voters were confident with their abilities to use the system, and used the verification wand sparingly, often only in cases where they were unsure of the mark they made. Failure to verify the entire ballot may have contributed to the wrong choice errors that were found.

Other subjects used the wand only to verify the holes they intended to mark (as opposed to checking to make sure the other holes did not contain stray or erroneous marks). This was fine if they wanted to verify that their mark was dark and complete enough to be read. This method could have caused problems should they have marked an incorrect hole the first time. By only verifying where they thought they should have marked, they could have ended up filling in two holes, leading to overvote errors.

Discussion, Study 1

Although it appears that Vote-PAD and paper ballots have similar user satisfaction ratings and per-contest error rates, blind voters take considerably more time to cast their ballots. The fact that they are slower is not particularly surprising; NIST estimates that a blind individual using the audio version of a completely accessible interface will take, at a minimum, 50% longer than a sighted user interacting with the visual display. That estimate is based on an optimal scenario, in which a blind user who is familiar with the alternative interface is taking a standardized test. The authors of the NIST document, based on their personal correspondence with individuals with visual disabilities, state that taking 3 to 4 times longer than a sighted user is probably more accurate (Laskowski et al., 2004). Study 1 produced comparable results, showing that blind voters using Vote-PAD take 5 times as long to vote, and blindfolded voters take more than 6 times as long to vote relative to sighted users voting on an identical bubble ballot.

The lengthy times generated by blind and blindfolded subjects is at some level a necessary function of the technologies used. The audio tape (including both the voting and verification sections) was 28 minutes and 34 seconds long. This can clearly be seen in the time of the blindfolded subjects (who took an average of 31 minutes). All of the blindfolded subjects chose to use the optional, separate verification stage and listen to the repetition of all candidates. They often paused the audiotape to ask for a reminder of the verbal prompts or to regain their bearings. Blind subjects that chose to use the audio interface tended to multi-task, and verify their selections in-line with the voting task.

They rarely paused the tape, and frequently asked for the prompts while the tape was running and introducing the next race.

While the audio length does not directly affect those using the Braille input, there is still a significant time disadvantage for Braille readers. The average reading speed for English prose text in the United State is between 250-300 words per minute (Bailey, 2000). In contrast, the average Braille reading speed is only 125 words per minute (National Library Service for the Blind and Physically Handicapped, 2006). Not only did Braille users have to read the ballot more slowly, but they also had to take additional time to read and interpret the navigational cues and explanations of page location.

Vote-PAD is classified as an assistive technology. The US technology-related assistance for individuals with disabilities act of 1988 defines an assistive technology as "Any item, piece of equipment, or product system, whether acquired commercially off the shelf, modified, or customized, that is used to increase, maintain, or improve functional capabilities of individuals with disabilities." Other examples of these technologies in use today by the blind population include text-to-speech based screen readers, screen magnifiers, and refreshable Braille displays. The National Health Interview Survey on Disability in 1994 reported 527,000 people use an assistive device for a visual impairment (United States Department of Health and Human Services, 1995). Blind voters' exposure to assistive technologies may offer an explanation for the drastic differences seen between blind subjects and blindfolded subjects. Just as sighted users are quite skilled and experienced at interacting with paper on a regular basis, so too are blind users experienced with using a wide range of assistive technologies in order to access things in their everyday life. Vote-PAD shares a strong relation with many of these technologies. It utilizes text-to-speech, tactile markers, Braille, and tactile/vibration feedback, all of which are enhancements that are regularly incorporated into assistive technology devices. This level of familiarity and skill could indicate why blind voters had similar, comparable error rates and SUS scores to sighted voters.

Blind voters' completion time in Study 1, although already five times slower than their sighted counterparts, is in all likelihood an underestimate of the real-world difference. Voting time did not include any of the instructional time during which subjects were taught how to use the ballot, tape player, verification wand, etc. It also did not include any time taken to use the included ballot shield or to privately deposit a vote into the ballot box (this phase of voting was not included in this study). The fact that blind voters are already disadvantaged when it comes to efficiency (because of slower Braille reading speeds and the length of text-to-speech audio translations), regardless of the interface used, makes it that much more important that the voting system they use be well designed and easy to utilize.

On the other hand, results on errors and satisfaction were encouraging. While with the limited sample size it is impossible to conclude that performance is identical to sighted voters with paper ballots, the results suggest that they are at least similar. This is meaningful, indicating that it is possible to construct voting systems that do not discriminate heavily against visually impaired users on what are probably the two most important metrics for this population. Care should be taken, however, not to interpret this as an endorsement or recommendation of tactile ballots in general or of Vote-PAD in particular. Different technologies have different strengths and weaknesses for different populations; systems like Vote-PAD do not not necessarily serve all populations (including election administrators) well. Instead, this should be viewed as an object lesson about what is possible and as a benchmark for accessibility; any future system intended to address the needs of the visually impaired should have to show that it can do at least as well as the results we have shown here.

Study 2

Study 2 expands upon the survey information collected from subjects in Study 1 to provide a more holistic view of the voting experience from the perspective of a visually impaired person. A large-picture understanding of the voting experience provides an environmentally valid platform for continuing research. Questions directly related to voting machine functionality provide definitive, evidence-based answers to design questions.

Approximately half of the questions asked in this survey were identical to those posed to sighted voters in previous experiments (see Everett et al., 2008 for example). Demographic information about the voter's age, gender, ethnicity, education, handedness, and native language was collected. They were surveyed on the amount of time they use a computer and are ask to self rate their computer expertise. Specific voting questions asked about the number of elections (national, governmental, and other) respondents had voted in, what types of machines or voting methods they used, and how often they participated in specific instances like absentee or straight-party voting. The purpose of these is to help understand for which populations these formats are most helpful, and who benefits the most from these extra provisions. Finally, voters were surveyed about their level of comfort with voting and their trust in the system as a whole (for example, "When you voted in an election, have you ever been unsure if your vote was cast correctly or would be counted? If yes, please describe the situation."). These identical questions allow for a direct comparison of important aspects of voting (like voter preferences and confidence in the process) between sighted and visually impaired populations.

Understanding difficulties with obtaining privacy and anonymity, as well as methods to help insure these requisite conditions, is another focus of this study. Specifically, interactions with poll workers were addressed, as well as voter confidence in both the people running an election and the system as a whole.

A survey completed by the National Federation of the Blind considers global aspects of voting and allows us to provide a more complete picture of the voting process (Hollander Cohen & McBride Marketing Research, 2008). Many general factors covered by this survey may lie outside the narrow focus of voting machine usability, but the combination of this information applied to voting system design may aide in providing election access to a very diverse population.

Method, Study 2

Subjects

Subjects were recruited and interviewed both in person and online. Twenty-two individuals were recruited in person at the National Federation of the Blind's state convention, and were compensated with $15 for their participation. One hundred and eighty people were recruited online through Internet correspondence sent to email lists, blogs, and message boards that serve the visually impaired community. Subjects completing the survey online were given a chance to express their thoughts and opinions, but were not compensated monetarily for their time.

The total 202 subjects (112 female, 76 male) ranged in age from 19-86, with a mean age of 50.42 (*SD*=13.5). Table 4 shows the frequency of the subjects' education levels; nine subjects did not report their level of education.

Table 4

Level of Education of Survey Respondents

	Number of People	Percentage of People
High school or less	25	13.0%
Some college	46	23.8%
Bachelor's degree or higher	122	63.2%

Table 5 shows the frequency of the subjects' ethnicity; 11 subjects did not report their ethnicity.

Table 5

Ethnicity of Survey Respondents

	Number of People	Percentage of People
African American	6	3.1%
American Indian	2	1.0%
Asian American	1	0.5%
Caucasian	176	92.1%
Mexican American or Chicano	3	1.5%
Multiracial	1	0.5%
Other	2	1.0%

The subjects' previous voting experience and number of elections voted is shown in Table 6. Only 5 subjects had never voted in any type of election.

Table 6

Previous Election Participation among Respondents

	Number of Elections Previously Voted In			
Election Type	0 Elections	1-8 Elections	9-15 Elections	15+ Elections
National-Level Elections	6	52	39	64
Governmental Elections	15	61	36	56
Local/Other Elections	36	63	39	33

All subjects reported being legally blind. "Legally blind" has a fairly broad definition that encompasses many levels of impairment. The *low vision* respondents are individuals retaining residual vision that allows them to read larger point text or regular text with the assistance of a magnifying glass. The *light perception* respondents are individuals that are able to tell light from dark and the general direction of the light source. And the *no vision* respondents are individuals with no vision or light perception. Table 7 displays the breakdown of respondents by magnitude of vision loss.

Table 7

Magnitude of Vision Loss among Respondents

	Number of People	Percentage of People
Low Vision	48	26.7%
Light Perception	24	13.3%
No Vision	108	60.0%

Procedure

All materials were read to the subjects that were interviewed in person. The respondent was seated across from the experimenter, with a microphone in the middle to record their answers. Subjects were first given a consent form and agreed that they were both over the age of 18 and considered legally blind. Following that, they received 54 questions including demographic questions, questions related to their previous voting experiences and questions about desired changes and future directions for the voting industry (see Appendix). Question formats included multiple choice, open-ended, and 5 or 10-point Likert scale questions. Subjects were given as much time as desired to respond. After completing the survey, they were debriefed regarding the nature of the experiment and given contact information if they desired to follow up on anything with the experimenters.

Subjects that completed the survey online read the materials themselves by any method they chose, such as increasing the font size, a screen reader, having a friend read it to them, etc. Those who received the survey online were given a link to SurveyGizmo, a survey tool that collected and reported their answers. Whenever applicable, an "other" option along with the direction to "please specify" and a text box were provided in an attempt to account for a wide range of experiences and preferences. The online survey only contained 52 questions, as two regarded hands-on interaction with a piece of technology.

Results, Study 2

The results of some of the general response questions are summarized in Table 8.

Table 8

Respondent Characteristics

- 16.4% of respondents would choose to use a visual display in addition to an audio interface while voting, if provided.
- Eleven percent of respondents report never having used Braille and 40% report being completely proficient Braille readers. If a Braille interface were offered, only 34.4% would choose to use Braille over an audio interface.
- When reporting computer skill (on a 10-point Likert scale with 1 being a novice and 10 being an expert) no one reported being lower than a 3 (2.2%) and 7.8% reported to be experts. The majority of respondents were experienced computer users, ranging between 7-9 (55%). 78.9% of respondents use a computer more than 20 hours a week. Older respondents tended to be less skilled and use computer less frequently than younger respondents. There were significant negative correlations between age and both computer skill (r (158) = -.20, p = .01) and usage (r (156) = -.20, p = .02).
- When asked about using an automated teller machine (ATM) to get money or complete a transaction, 23.9% of respondents never use one, 28.0% use one occasionally (several times a year), and 39.4% use one often (at least once a month).

The similarities between the study populations of both blind and sighted individuals can be seen in Table 9. The only significant difference between the two groups is the level of self-reported computer expertise, with visually impaired subjects rating themselves as more competent than did the sighted subjects (χ^2 (9, N = 308) = 41.08, p < .001, Cramer's V = .37).

Table 9

Study population of sighted and blind individuals

	Sighted Population	Blind Population
Mean age	46.8 (*SD*=17.6)	51.8 (*SD*=12.8)
Computer expertise	6.08 (*SD*=2.6)	7.24 (*SD*=1.7)
Gender (% female)	52.8%	59.6%
Typically vote absentee	14.5%	12.3%
Typically cast a vote for every office	65.1%	72.3%
Time pressure caused to rush	18.3%	22.6%
Worried about figuring out technology	37.3%	31.2%

Accuracy and Election Confidence

During an election, 31.2% of respondents have worried about figuring out how to use the technology to cast their vote and 22.6% felt that time pressure caused them to rush or make a mistake. Only 16.3% of respondents reported they never review their completed ballot before casting it and 38.8% always review their ballot. Over half of respondents (58%) indicated that having a way of directly verifying that their ballot accurately represented how they intended to vote was an essential part of any voting system. Only one respondent felt that the ability to review the ballot was unimportant.

Audio Interface

There was a slight preference overall among respondents for a voting machine's audio to use a recorded human voice (55.3%) rather than a synthesized text-to-speech program. There was a significant difference in preference between levels of vision (χ^2 (2, N = 152) = 7.05, p = .03, Cramer's V = .22), see Figure 8. A follow-up test between the no vision and light perception groups found no significant preference for either type of audio (χ^2 (1, N = 108) = 1.26, p = .26). Among low vision respondents, there was a significant preference for recorded human voices (χ^2 (1, N = 44) = 7.36, p = .01).

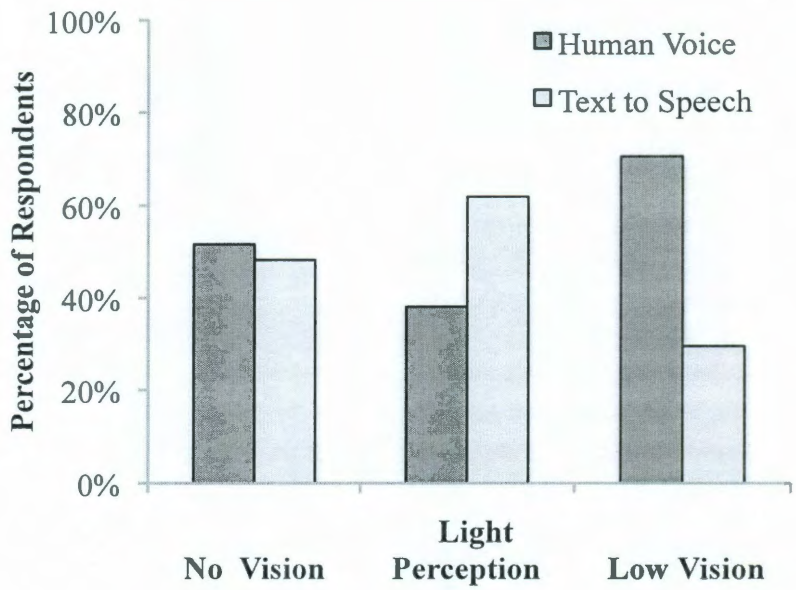

Figure 8. Percentage of respondents in category of visual ability and their preference for type of DRE audio.

85.4% of respondents were familiar and comfortable with using and understanding synthesized voices (by responding 8 or higher on a 10-point Likert scale). Comfort varied significantly across level of vision (χ^2 (16, N = 158) = 31.96, p = .01, Cramer's V = .32), with no vision users being more comfortable than low vision users (χ2 (8, N = 137) = 24.28, p = .002, Cramer's V = .42). Most respondents had no preference regarding the gender of the audio voice, but among those with a preference male voices were significantly more preferable (χ^2 (1, N = 63) = 26.68, p < .001). There was no significant difference in desired audio gender based on the respondent's own gender, χ^2 (1, N = 58) = 1.73, p = .19. .

The ability for the user to be able to change audio volume and speed were both highly desired aspects of a computerized audio interface (83.9% and 79.4%, respectively). Other desired audio controls included ability to change pitch (42.8%) and language (21.7%) to a lesser extent (Figure 9).

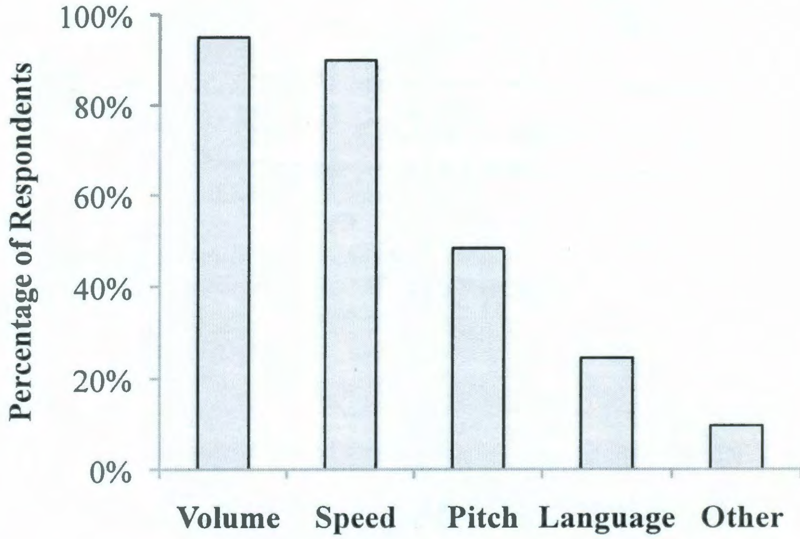

Figure 9. Percentage of visually impaired voters that would like to be able to adjust the given setting on an audio interface.

Multiple Modalities

Some voting machines offer multiple modalities to help accommodate the large diversity present in the voting public. If provided, 16.4% of respondents would like to use a visual and audio mode simultaneously.

If it were available, 34.4% of respondents would prefer to use a Braille interface instead of an audio interface. A significant relationship between a respondent's Braille ability and their desire to use the Braille interface was found (and as expected, better Braille readers responded that they would prefer a Braille interface more often), r (151) = .55, $p < .001$. There was also an influence of individual preference beyond just the ability to read Braille. Out of the 64 total respondents that reported completely proficiency with reading Braille (a 10 on a 10-point Likert scale), over a third (37.5%) still would prefer to use an audio interface. There was no significant preference between a Braille interface and an audio interface, χ^2 (1, N = 63) = 3.57, p = .59 among Braille readers.

Input Devices

Respondents were asked to think about how comfortable they would be with using different methods to control their interactions with a voting machine. A substantial majority of respondents (88.5%) said they would be comfortable with a directional keypad (arrow keys) and even more—90.4%—said they would be comfortable with a telephone keypad. 95.6% of respondents were very proficient (8 or higher on a 10-point Likert scale) with using a telephone keypad to enter numbers. Table 10 shows the types of input devices used by respondents to interact with their computers on a daily basis.

Table 10

Input Devices Used

	Number of People	Percentage of People
Keyboard	163	99.4%
Mouse	35	21.3%
Microphone/Speech Recognition	13	7.9%
Touch screen	9	5.5%
Joystick	1	0.6%

There was a significant relationship between a respondent's computer skill and their comfort using directional arrows, with more experienced computer users being more comfortable with using arrow key inputs, r (151) = .17, p = .04. No relationship between a respondent's computer skill and their comfort using a telephone keypad was found.

90.9% of responders reported keyboards to be their preferred method of input when using a computer (followed by a mouse, 4.9%, a touch screen, 1.8%, and a joystick, 0.6%).

Subjects surveyed in person were asked two questions concerning a proposed input device, the button box, which they had the opportunity to feel and explore tactilely (see Figure 3). 85% of respondents (17 out of the 20) said that they felt the six different buttons on the button box were easy to discriminate and tell which one performed which function. 1 respondent felt this task was difficult, and the final 2 respondents rated the level of difficulty as average. Most respondents (75%, 15 out of 20) felt the button size was fine. 4 respondents would have preferred to have smaller buttons, and 1 respondent would have preferred to have larger buttons.

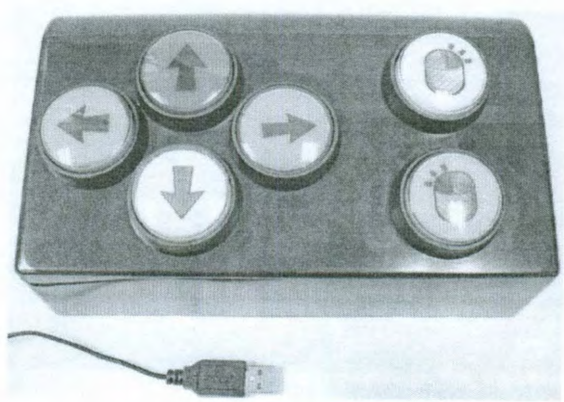

Figure 10: Large, tactile button box proposed as a possible DRE input method in future mock election studies.

Voting Experiences

It is often the case that multiple options for voting exist; absentee ballots in alternative formats such as regular, large print, Braille, or tactile are not unusual. However, a majority of respondents chose to vote in person; only 12.3% typically voted using an absentee ballot. The NFB (2008) survey found that 62% of blind voters chose to vote at the polls.

Straight-party voting is the practice of voting for candidates of the same political party for multiple offices. In some states, there is a single option on the ballot that allows a voter to cast a vote for a selected political party for every partisan race. A total of 16 states presently offer some form of straight-party voting on the ballot. Table 11 shows a breakdown of survey respondents that have previously voted in one or more states that offer straight-party voting. 9.3% of respondents always chose to vote a straight-party ticket. 23% usually voted straight-party, 37.9% sometimes voted straight-party, and 29.8% never voted straight-party. Out of respondents that have voted in 1 or more states where a straight-party voting ballot option was available, 60.4% did so by voting in each race individually and 39.6% used the single straight-party option on the ballot.

Table 11

Respondent Access to Early Voting and Straight-Party Voting

	Voted in a Straight-Party Voting State		Voted in an Early Voting State	
	Number of People	Percentage of People	Number of People	Percentage of People
Yes	71	56.2%	106	65.4%
No	91	43.8%	56	34.6%

When asked about their participation in early voting, 48.4% of respondents never early vote, 25.8% sometimes early vote, 14.5% usually early vote, and 11.3% never early vote. These results are similar to those from the NFB survey (2008) which found that early voting was used of by 16.2% of respondents in the 2008 election. This is a fairly substantial proportion, considering only 32 states (plus the District of Columbia) offer in-person early voting as an option (National Conference of State Legislatures, 2010). The distribution of respondents that have voted in one or more of these states can be found in Table 11.

When querying respondents that have voted in 1 or more states where early voting was available, over a third of respondents (37.4%) usually take advantage of early voting opportunities, 28.3% sometimes do, and only 34.3% never do. Table 12 compares survey respondents to the general population of the 2008 Election (U.S. Election Assistance Commission, 2008) and the NFB survey of blind voters in the 2008 Election (Hollander Cohen & McBride Marketing Research, 2008) and also includes relevant numbers collected in Study 2 regarding typical voting habits.

Table 12

Voting Methods Used By Different Populations

	General Population, 2008 Election	Blind Voters, 2008 Election	Blind Voters, Study 2
In person, on Election Day	60.2%	45.9%	
Absentee Ballot	17.3%	38.0%	12.3 % [1]
Early Voting	13.0% [2]	16.2% [3]	51.6% [4]
Provisional Ballot	1.4%		

[1] Typically cast their vote by absentee ballot
[2] This increases to 25.7% when only considering states that allow early voting.
[3] 26% of blind voters that voted at the polls (rather than by absentee ballot) used early voting
[4] Sometimes (25.8%), Usually (14.5%), or Always (11.3%) used early voting. This increases to 65.7% when only considering respondents that have voted in 1 or more states where early voting was available

Most respondents (85.2%) reported that they never cast a write-vote. 14.2% sometimes cast a write-in vote and 0.6% (1 respondent) always chose to cast a write-in vote. Most respondents (72.3%) also cast a vote for every office on the ballot.

Poll Worker Relations

Most respondents (92.2%) have received assistance during the actual process of voting, from family, friends, a poll worker, or someone else. Table 13 shows a detailed division of the type of assistance received.

Table 13

Type of Assistance Received by Respondents

Type of Assistance	Percentage of People
Family Member	65.1%
Poll Worker	58.4%
Friend	41.0%
Other	9.6%
Never received assistance/ No assistance required	7.8%

Out of the respondents that have used assistance during voting, 58.4% have received help from a poll worker. The majority of respondents (84.3%) trusted the poll workers to provide them with accurate information. A quarter of respondents (24.4%) said that poll worker attitude is an obstacle that they feel makes it difficult for them to vote. This was exacerbated when the respondent had previously been assisted by a poll worker and these individuals were significantly more likely to mention that poll worker attitude was a problem, χ^2 (1, N = 166) = 5.04, p = .03, Cramer's V = .17. No relationship between receiving assistance from a poll worker and trust in a poll worker was found.

These results are consistent with the NFB (2008) survey: of the 191 individuals that were offered/asked for an accessible machine, 19% experienced problems obtaining one. "Not having an accessible machine translated into poor opinions of how they were treated by poll workers, as only 41% of the neutral and dissatisfied felt they were treated as if they were capable of voting independents, just 50% felt they were given the same privacy as other voters, and only 67% felt they were treated wit the same dignity as other voters." About 1 in 5 voters overall said poll workers had trouble setting up or activating an accessible voting machine – most often indicating the individual did not know how to activate the audio ballot or did not know how to operate the machine.

Obstacles

Multiple obstacles at or getting to the polls exist for blind voters beyond the attitude of poll workers, although that was the most mentioned barrier. Table 14 categorizes the most frequent responses. Over two-thirds of respondents (67.3%) reported they faced one or more obstacle.

Table 14

Reported Obstacles at the Polls

	Number of People Affected	Percentage of People Affected
Attitude of poll workers	44	22.4%
Location of polling station	38	21.1%
Length of time it takes to vote	35	19.4%
Physical layout of polling station	30	16.7%
Long lines	19	10.6%
No friend/family member available to help	19	10.6%
Hours the polls are open	11	6.1%

Qualitative Responses

Numerous respondents provided free-response comments that were particularly interesting or insightful. For example, issues involving multiple disabilities were raised: "The reason I prefer a male voice is that I have a hearing loss and those voices are easier for me to hear."

A key area of dissatisfaction among blind voters was the lack of appropriate audio controls on the DRE. In particular, control of speech rate was a common complaint. For example: "The most cumbersome was not being able to adjust the rate of the synthetic speech. It was at a very slow rate of speech and I customarily use a higher rate." One respondent elaborated "I'd like it better if audio machines demonstrated to beginning users how to change the speed right away; it took forever for this slow talker of a man to get to it and I had an to rush out of there without reviewing the ballot because of it." Poll workers were another common source of complaint: "Generally speaking, I have found the poll workers to be poorly trained, and resistant to my use of the adaptive technology, encouraging me to be assisted as I had in the past." Another mentioned "It wouldn't hurt to put polling workers through some disability awareness/sensitivity training to make it a better experience for those of us with disabilities."

Discussion, Study 2

Accuracy

To review a ballot a sighted voter only needs to look at the paper or computer screen and verify that how they intended to vote is the same as the answer that is marked on their ballot. Visually impaired voters must often take someone's or something's word that their ballot represents their intentions, as there are very few ways for them to directly verify what is on the paper. Paper-based non-computerized systems like Vote-PAD use a tactile feedback mechanism in the form of the light-sensing wand to allow voters to verify their marks. All but one survey respondent felt that some method of ballot review was an important aspect to include in a voting system. However, only a little over a third (38.8%) of blind voters reported that they always review their ballot.

Ballot review needs to be an available option, for times when a voter is uncertain or needs to double check a race. In other situations, a long and tedious review process can actually become a hindrance. A new DRE design should aim to strike a balance between the two, with a review process available when needed but not a prerequisite for casting the ballot.

Interface Options

The use of an audio interface either by itself or conjunction with another modality (such as a visual or refreshable Braille display) is fundamental to providing an accessible DRE interface. Allowing multiple options to be tailored by voters to suit their own needs is critical. Most of the survey respondents have experience with screen readers (pieces of software that are used to convert computer and web content into audio navigation). Experienced users set the speech rate upwards of 300 words per minute, a speed far faster than an inexperienced listener could comprehend (WebAIM, n.d.). DRE interfaces should allow voters to capitalize on this expertise, as it is not unusual for auditory interfaces to have extremely steep time costs relative to visual interfaces as was shown in Study 1.

The type and gender of audio should be selected so that the interface is useable by the largest amount of people, while making sure not to exert any outside influence on the process of voting. Couper, Singer, and Tourangeau (2004) examined the use of different types (recorded human voice, human-sounding TTS, and machine-like TTS) and genders of voice in an automated telephone interactive voice response (IVR) survey. Subjects were adept at differentiating between the the three types of voices. Their research did not find any significant differences across the three types of voices in the subjects' accuracy of reporting socially desirable/undesirable behaviors, reactions to the different voices, and break-off rates across different conditions. This indicates that while participants can and do differentiate between different types of voices, the type and gender of the voice probably doesn't influence how the subject responds to the interface or the material. Breakoff rates (a measurement of the number of respondents that fail to complete the survey by hanging up either while they're being transferred to the IVR system or during the middle of the survey) may be relevant when considering ballot roll-off. Couper, Singer, and Tourangeau found no differences in breakoff rates across the 3 IVR voice types, which indicates the choice of audio should at least not exacerbate the occurrence of ballot roll-off. The survey used in their research included both gender-related attitude measures (items regarding the roles of men and women) and sensitive items involving gender (items on sexual activity). The gender of the voices was randomized, and no consistent effects of the gender of the voices used was found. Both these results suggest that respondents appear to be relatively immune to audio features of an interface.

Braille interfaces have been discussed as a viable alternative for blind voters. Braille provides visually impaired individuals with a special system designed exclusively to allow them to read and interact with the world. But when designing a voting system, the number of Braille readers (approximately 10% of legally blind adults) makes this impractical. Braille is usually only learned by those that are visually impaired from a young age and attend a school that offers a Braille literacy program. Hollander Cohen & McBride Marketing Research (2008) found that on average study respondents learned to read Braille at age 19, with 50% of Braille readers learning it before age 10. A Braille-based voting system would fail to take into account the large portion of the population that has vision problems due to aging.

Out of the 64 expert Braille readers among the survey respondents (defined as having self-rated themselves as a 10 out of 10 on Braille reading ability), over a third would still prefer to use an audio interface rather than a Braille interface. The question of the "best" modality is not just a matter of ability, but also of preference. This underlines the need to offer options so that people can tailor the voting experience to their unique needs. Designers should not make assumptions about what works best for an entire group of diverse individuals. One possible solution would be to combine elements of Braille into an existing interface, such as Braille button labels. These would appeal to and enhance the experience of even novice Braille readers, while not distracting from the overall interface or being a necessary part of being able to vote.

Levels of Vision

The magnitude of someone's vision loss directly impacts the type of technology they come into contact with on a daily basis. Low vision users may be adept at utilizing their own magnifying tools to make regular print, computer screens, and publicly accessible terminals (like ATMs or airport check-in kiosks) accessible to them. Users with no vision may be comfortable with listening to text-to-speech computerized voices like those that are used in screen readers and be able to listen to them at a rapid pace that would be unintelligible to those with no experience with speeded up audio.

Furthermore, respondents with no vision rated themselves as significantly more comfortable with listening to and understanding synthesized audio. Out of 112 no vision or light perception respondents, only 4 people (3.6%) rated themselves at a 5 or less on a 10 point scale, indicating relatively little exposure and comfort with using this type of audio. On the other hand, 8 out of 46 low vision respondents (17.4%) rated themselves a 5 or less. This division between technologies can also be seen in the preferences for type of DRE audio, with low vision users preferring a human voice, and no vision users showing no preference between human or synthesized voices.

Input Devices

The relationship between a respondent's computer skills and their level of comfort with using directional arrow keys can be understood in terms of the keyboard, the preferred input device by a majority of users. Arrows keys are an integral part of navigation a webpage or document using a screen reader. This level of familiarity and comfort could be taken advantage of and designed into a voting machine's input device.

Poll Workers

With almost two-thirds of the blind population choosing to vote in person, it is essential that accessible voting machines that allow people to cast a secret ballot be provided. This is one of many obstacles to overcome at the polls. The most evident in the open-ended survey results was the interaction between the voters and the poll workers. The expressed problems included a desire for more training of the poll workers on how to use the technology, how to assist people with disabilities, and a general acceptance of accessible technology. Accessible voting options (like large print, audio, or even Braille interfaces) need to be integrated with all voting machines so the process is no different from a poll worker's perspective. Alternatively, machine manufacturers should endeavor to provide a simple setup that poll workers with limited technological experience can successfully complete.

In general, the NFB Survey (Hollander Cohen & McBride Marketing Research, 2008) found that the instructions given to voters regarding the use of the voting machines were adequate, especially since most audio interfaces also have built-in systems of help and instructions. 84% of voters in the 2008 election said they were provided with clear instructions on how to use the voting machine or didn't need them at all. Out of those that did receive instructions, 92% felt these instructions were just right rather than too complicated or too simplistic. This appears to corresponds with the poll workers reported level of comfort. The Citizens Union Foundation reported that 77.3% of poll workers felt knowledgeable about demonstrating how to use a voting machine. This was also a task that most poll workers (70.6%) performed at some point on election day.

Poll workers volunteer for the position and are usually paid close to minimum wage. Training of poll workers varies between districts. Some poll workers receive comprehensive training courses whereas other poll workers receive no training at all. For example, the state of Texas offers an online training course (from http://www.texaspollworkertraining.com/) that can be distributed to poll workers. The course does provide guidelines for "Assisting Voters with Disabilities," including mobility, hearing, and visual disabilities. There is one page of guidelines for ensuring accessibility for people with visual impairment. The process of checking in, escorting the voter to and from their voting station, and the treatment of service animals are all covered, but the program completely fails to address any part of the actual means of casting a ballot (Figure 11).

Accessibility for People with Visual Impairments

1. Identify who you are, where you are, and how you will be assisting the voter.
2. At the Qualifying Table:
    - Describe what you are doing as you do it;
    - Let the voter know when you need them to do something;
    - Provide a ruler to make signing on a line of the Signature Roster easier.
3. Escorting the voter through the polling place:
    - Talk the voter through the polling place;
    - Announce your destination and how far it is or how long it will take to get there;
    - Describe turns and obstacles;
    - Offer your arm; don't take the voter's arm;
    - Tell the voter when you are leaving them at the voting station;
    - Tell the voter who to ask for when they are ready to move again.
4. Don't distract a service animal from its job:
    - No petting or playing with the animal;
    - No treats;
    - No talking to the animal.

Figure 11. Excerpt from the State of Texas Online Poll Worker Training Program (The State of Texas, n.d.)

A 2006 initiative by the Citizens Union Foundation in New York sought to address the shortage of poll workers and especially to recruit college-age poll worker applicants. A part of their project included sending a survey to all of the poll workers after the 2006 general election covering their experience at the polls, training sessions, and various tasks performed. Only 5.7% of the poll workers surveyed did not have any training before election day. About half (56.6%) of those who did attend training were introduced to an actual voting machine during that training and 45% recommended that they train on a voting machine during the class. When asked about their level of comfort performing certain tasks, only a third of poll workers (32.9%) said they would feel comfortable setting up a machine without assistance. The Citizens Union Foundation had several suggestions in line with the need for more practical training for the New York Board of Elections. These included encouraging "hands-on" demonstrations of the voting machines and mandatory training for all poll workers regardless of past experience.

Training issues are relevant because many DRE systems used today need to be rebooted and go through a set up process in order to put them into an accessible, audio mode. This level of technical familiarity would require a poll worker with the knowledge of how to set up a machine and could be gained through a training program on the actual election equipment. If an accessible machine was not available, respondents in the NFB's Survey (Hollander Cohen & McBride Marketing Research 2008) had to spend an average of 15 minutes waiting for poll workers to set up the machine. Perceived negative treatment by poll workers was partially dependent on whether or not a voter was provided with an accessible machine. Having the machines available and poll workers with the technical knowledge of how to set them up is essential to cutting down wait and voting times, and increasing voter satisfaction.

Voting Experience

As was demonstrated in Study1 there is a substantial time difference between sighted and visually impaired populations' voting times. This adds an extra incentive for blind voters to take advantage of both early voting and straight party voting. In early voting, individuals can arrive when it is convenient for them. This freedom of day and time may help alleviate their reliance on others, an obstacle mentioned by 10.6% of respondents.

Straight party voting provides a one-question solution to vote on the majority of the ballot (excluding non-partisan races and propositions). A time benefit for straight party voting was not seen among the general population but it might be relevant among a population that takes five times longer to vote (Campbell & Byrne, 2009). The improvement would also depend on how people choose to straight party vote; either by using the single ballot option (giving them a large time benefit if they were able to skip or skim through the already-voted races without reviewing them) or by voting in each race individually (which would most likely result in a similar voting time to voters that chose candidates of varying parties). A consistent order of parties on the ballot such as the Republican candidate always being listed first, Democratic candidate second, and Libertarian candidate third (as was the case with the ballot used in Study 1) may be highly beneficial to voters utilizing only the audio interface. These regular landmarks cold be used as an indicator of how far into a race one is, and used by voters to orient themselves on the ballot.

General Conclusions and Future Directions

Now that baseline measures have been obtained for tactile paper ballots, it will be possible in the future to compare other types of accessible voting technologies to determine if they, too, show error rates and subjective satisfaction comparable to sighted users voting on paper ballots. Perhaps other technologies can improve upon ballot completion time as well, though it's suspected that this is an inherently difficult limitation to overcome. Naturally, the primary voting technology of interest for future research is the DRE. The development and testing of DRE using an auditory interface with blind voters will be essential to understanding the strengths and limitations of the platforms currently deployed in many polling places. Only after comparisons can be made between

DREs and other technologies can a viable course of action for providing equal voting rights to the entire population be determined.

One focus of these studies was to observe how blind voters differ, if at all, from the sighted population. As can be seen in Table 9, the age range and gender division of the two subjects pools was very similar. Blind users rated themselves as higher in computer expertise. This is in part due to the majority of the survey responses from blind voters being collected on the computer using an online polling site. To be able to respond to the survey in the first place required a large amount of computer knowledge and comfort with using accessible technologies (like a screen reader). Beyond this limited context, visually impaired individuals also need to use computer systems in many daily tasks in order to interact with the visual world. Both these factors explain why computer expertise is the only significant difference between the sighted and blind subjects. In Study 1, only voting time differed between blind and sighted voters, with error rates and satisfaction scores remaining consistent. In the survey, both blind and sighted groups of users were similar in the ways they chose to vote and any hinderances faced regarding the voting technology.

Physical, auditory, and cognitive disabilities lie far outside the range of this study. However, individuals with these disabilities make up a portion of the voting population and HAVA requires that polling places address all of these situations. It is important to obtain measures of the accessibility and usability of current voting systems by voters with a wider range of disabilities. It is also important to address the needs of voters with multiple disabilities. There exists a large diversity among disabilities, and the number of individuals with any one combination of functional limitations is much smaller than each of the broad sub-categories. Solutions targeted to address the needs and abilities of a single, specific disability may not be useful to this wider audience. According to the National Healthy Interview Survey (1983-1985, in LaPlante, 1988), 74% of people who are blind report other impairments. This calls to light the importance of systems that provide multi-modality interactions. As Vanderheiden (1990) points out, "When products, environments or systems are made more accessible to persons with limitations, they are usually easier for more able-bodied persons to use. Some of the potential benefits include lower fatigue, increased speed and lower error rates." Multi-modality audio and visual systems may improve the voting experience beyond visual impairment and impact individuals with other factors like aging, cognitive impairment or language-based disorders. The current study may inform design aspects of voting systems, as well as the broader range of interactive technologies, for the general population.

Large surveys of blind respondents provide us with a better understanding of voter abilities, needs, and desires. Thorough analysis and observation will help lead to an end goal of providing highly usable multimodal ballot technology for the blind and visually impaired population. Parts of this survey were used as an exploratory forum for respondents to voice their opinions, describe detailed experiences, and to fill in any aspects of voting they felt had been neglected in the survey. These responses provided valuable insight and put a personal voice behind the main findings of this survey, as well as providing details about aspects of voting that need to be addressed in future inquiries.

Results from Study 2 suggest certain guidelines be followed based on the data collected in this survey and often supported by outside sources. An accessible DRE interface should include an audio mode that can be used in conjunction with the standard visual display. A synthesized text-to-speech voice (chosen over the slightly preferred human voice due to the ability to speed up the audio, a highly desired option) that can be sped up without distortion should be used. The audio voice should be male, which provides a lower frequency that is more audible by individuals with hearing disabilities. This system should provide the ability to adjust audio volume, text size, and screen contrast. Navigation should allow users to skip through sections of speech that are not important to them as well as allowing them to replay any parts they may have missed or not comprehended the first time. A way of reviewing the ballot must be included but should not be required in order for a voter to cast their ballot. Poll worker training should include use of the actual voting machine, as well as examples of how the accessible interfaces work and the most efficient way to set them up.

By combining the unique perspective of visually impaired votes with a solid understanding of human factors best practices, a voting system that is both accessible and useable can be designed. The integration of accessibility into mainstream technology often has benefits beyond allowing more of the population access to a system. The results from the two studies present here will inform upcoming research and directly impact how the input devices and user response or interactions are designed in a future accessible DRE. Using the mock election results from Vote-PAD, a non-computerized technology, as a baseline, a direct comparison between the usability of different accessible technologies can be obtained. There will be an emphasis in future studies on utilizing the survey responses in order to make informed decisions during the design process, ultimately with the goal of devising a multi-modality accessible interface that out-performs currently available systems.

References

Bailey, B. (2002). User Interface Design Update. Retrieved April 9, 2008 from http://www.keller.com/articles/readingspeed.html

Bangor, A., Kortume, P. T., & Miller, J. T. (2008). An Empiracle Evaluation of the System Usability Scale, *International Journal of Human-computer Interaction*, 24: 6, 574-594.

Bederson, B. B., Lee, B., Sherman, R. M., Herrnson, P. S., & Niemi, R. G. (2003). Electronic voting system usability issues. In *Human Factors in Computing Systems: Proceedings of CHI 2003*, (pp. 145–152). New York: ACM.

Brooke, J. (1996). SUS: A "quick and dirty" usability scale. In P W Jordan, B Thomas, B A Weerdmeester & A L McClelland (eds.) *Usability Evaluation in Industry*. London: Taylor and Francis.

Byrne, M. D., Greene, K. K., & Everett, S. P. (2007). Usability of voting systems: Baseline data for paper, punch cards, and lever machines. In *Human Factors in Computing Systems: Proceedings of CHI 2007*, (pp. 171-180). New York: ACM.

Campbell, B. A., & Byrne, M. D. (2009). Now do voters notice review screen anomalies? A look at voting system usability. *Proceedings of the 2009 Electronic Voting Technology Workshop/Workshop on Trustworthy Elections* (EVT/WOTE '09).

Campbell, B. A., & Byrne, M. D. (2009). Straight party voting: What do voters think? *IEEE Transactions on Information Forensics and Security, 4*(4), 718-728.

Citizens Union Foundation. (2006). Project Report: 2006 Poll Worker Recruitment Program. Retrieved March 31, 2011 from http://www.citizensunion.org

Couper, M. P., Singer, E. & Tourangeau, R. (2004). Does Voice Matter? An Interactive Voice Response (IVR) Experiment. *Journal of Official Statistics, 20* (3), 551-570.

Cross, E.V., Dawkins, S., McClendon, J., Sullivan, T., Rogers, G., Erete, A., and Giblert, J.E. (2009). Everyone Counts: Voting Accessibility. In C. Stephanidis (Ed.), *Universal Access in Human-Computer Interaction. Applications and Services* (pp. 324-332). Berlin/Heidelberg: Springer.

Everett, S. P., Byrne, M. D., & Greene, K. K. (2006). Measuring the usability of paper ballots: Efficiency, effectiveness, and satisfaction. In *Proceedings of the Human Factors and Ergonomics Society 50th Annual Meeting*. Santa Monica, CA: Human Factors and Ergonomics Society.

Everett, S. P., Greene, K. K., Byrne, M. D., Wallach, D. S., Derr, K., Sandler, D., & Torous, T. (2008). Electronic voting machines versus traditional methods: Improved preference, similar performance. *Human Factors in Computing Systems: Proceedings of CHI 2008* (pp. 883-892). New York: ACM.

Greene, K. K. (2008). *Usability of New Electronic Voting Systems and Traditional Methods: Comparisons Between Sequential and Direct Access Electronic Voting Interfaces, Paper Ballots, Punch Cards, and Lever Machines*. Master's Thesis, Rice University, Houston, TX.

Greene, K. K., Byrne, M. D., & Everett, S. P. (2006). A comparison of usability between voting methods. In *Proceedings of the 2006 USENIX/ACCURATE Electronic Voting Technology Workshop.* Vancouver, BC.

Hollander Cohen & McBride Marketing Research (2008). Blind Voters Experience Assessment Study Research Summary [PowerPoint slides]. Retrieved from the National Federation of the Blind Voting, Accessibility, & the Law site: http://www.nfb.org/nfb/HAVA_legislation.asp

Laskowski, S. J., Autry, M., Cugini, J., Killam, W., & Yen, J. (2004). Improving the usability and accessibility of voting systems and products. NIST Special Publication 500-256.

Mebane, Jr., W. R. (2004). The wrong man is president! Overvotes in the 2000 presidential election in Florida. *Perspectives on Politics, 2*(3), 525-535.

National Conference of State Legislatures. (2010). Absentee and Early voting. Retrieved February 10, 2011 from http://www.ncsl.org/LegislaturesElections/ElectionsCampaigns/AbsenteeandEarlyVoting/tabid/16604/Default.aspx

National Federation of the Blind. (1986). LEGALLY BLIND, legal definition. Retrieved April 9, 2009 from http://www.nfb.org/nfb/Legally_Blind_Definition.asp

National Federation of the Blind Jernigan Institute. (2009). The Braille Literacy Crisis in America. Available from http://www.nfb.org/images/nfb/documents/pdf/Final %20Braille%20Literacy%20 Report_ Secure.pdf

National Library Service for the Blind and Physically Handicapped. (2006). NLS Factsheet: About Braille. Retrieved April 9, 2009 from http://www.loc.gov/nls/reference/factsheets/braille.html

Nichols, S. M., & Strizek, G. A. (1995). Electronic voting machines and ballot roll-off. *American Politics Quarterly, 23*(3), 300-318.

Piner, G. E. & Byrne, M. D. (2010). Baseline Usability Data for a Non-Electronic Approach to Accessible Voting. *Proceedings of the 2010 Electronic Voting Technology Workshop/Workshop on Trustworthy Elections* (EVT/WOTE '10).

Piner, G. E. & Byrne, M. D. (in press). The Experience of Accessible Voting: Results of a Survey among Legally-Blind Users. P*roceedings of the Human Factors and Ergonomics Society 55th Annual Meeting*, Las Vegas, NV: Human Factors and Ergonomics Society.

Resnikoff S, Pascolini D, Etya'ale D, et al. (2004). Global data on visual impairment in the year 2002. *Bulletin of the World Health Organization, 84*(11), 811-890.

Rhode Island Office of the Secretary of State. (n.d.) Guidelines for Braille and Tactile Ballots. Retrieved April 9, 2009 from http://www.sec.state.ri.us/elections/voting/blindordisabledvoters/blindordisabledvo ters/Br ailleTactileBallotGuidelines.html

Runyan, N. (2007). *Improving access to voting: A report on the technology for accessible voting systems.* Retrieved October 1, 2008 from http://demos.org/pubs/improving_access.pdf

The State of Texas. (n.d.) Online Poll Worker Training Program. http://www.texaspollworkertraining.com/

United States Department of Health and Human Services. (1995). National Health Interview Survey. Hyattsville, MD.

United States Government, 47th Congress. (2002). Help America Vote Act of 2002. Public Law 47-252. Washington, D.C.

United States Government. (1990) Americans with Disabilities Act of 1990, Public Law 101- 336. Washington, D. C.

U.S. Census Bureau. (2005). Americans with Disabilities. Retrieved January 20, 2011 from http://www.census.gov/prod/2008pubs/p70-117.pdf

Vanderheiden, G.C. (1990). Thirty-something million: should they be exceptions? Human Factors, 32(4), pp. 383-396.

Vote-PAD, Inc. (n.d.). Accessible Voting Without Computers. Retrieved October 1, 2008 from http://www.vote-pad.us

Wand, J. N., Shotts, K. W., Sekhon, J. S., Mebane, W. R., Jr., Herron, M. C., & Brady, J. E. (2001). The butterfly did it: The aberrant vote for Buchanan in Palm Beach County, Florida. *American Political Science Review, 95*(4).

Wed Accessibility In Mind (WedAIM). (n.d.). Designing for Screen Reader Compatibility. Retrieved February 10, 2011 from http://webaim.org/techniques/screenreader/

Appendix
Survey Items

1.) What is your gender?
( ) Male
( ) Female

2.) How old are you?

____

3.) While this research is currently focused on elections in the United States, we are interested in responses from those from other nations as well. If the voting experiences you are answering this survey about did NOT take place in the United States, please list what country or countries you are referring to

____

4.) Are you a native English speaker? If no, what is your native language?
( ) Yes
( ) No

5.) Please indicate the highest level of education you have completed.
( ) Some high school
( ) High school or G.E.D.
( ) Some college or Associate's degree
( ) Bachelor's degree of higher

6.) What ethnicity do you consider yourself?
( ) African American
( ) American Indian
( ) Asian American
( ) Caucasian
( ) Mexican American or Chicano
( ) Other Hispanic or Latino
( ) Multiracial
( ) Other

7.) Are you left or right handed?
( ) Left-handed
( ) Right-handed
( ) Ambidexterous

8.) Do you have any residual vision? If yes, please describe.

____

9.) Please rate your level of proficiency with reading Braille (With 1 meaning "I've never used it", and 10 meaning "I'm completely proficient"):
( ) 1
( ) 2
( ) 3
( ) 4
( ) 5
( ) 6
( ) 7
( ) 8
( ) 9
( ) 10

10.) How many hours per week do you use a computer?
( ) Less than 5 hours
( ) Between 5 and 20 hours
( ) Between 20 and 40 hours
( ) Over 40 hours

11.) Please rate your level of computer expertise (With 1 being a novice, and 10 being an expert)
( ) 1
( ) 2
( ) 3
( ) 4
( ) 5
( ) 6
( ) 7
( ) 8
( ) 9
( ) 10

12.) Which of the following input devices do you use to interact with your computer? (Please choose all that apply)
[ ] Keyboard
[ ] Mouse
[ ] Joystick
[ ] Touch screen
[ ] Microphone/Speech Recognition
[ ] Other (please specify)

13.) What is your preferred method of input when using a computer?
( ) Keyboard
( ) Mouse
( ) Joystick
( ) Touch screen
( ) Microphone/Speech Recognition
( ) Other

14.) How often do you use an ATM (Automated Teller Machine) to get money or complete other transactions at a bank, grocery store, or other location?
( ) never
( ) very infrequently
( ) occasionally (for example 1-4 times a year)
( ) often (for example once a month)
( ) frequently (for example once a week or more)

15.) How many national-level elections (that is, elections for President or Congress/ Senate, typically held every two years; both 2004 and 2006 would count for this) have you voted in?
( ) None
( ) 1-8
( ) 9-15
( ) More than 15

16.) How many non-national, but governmental, elections have you voted in?
( ) None
( ) 1-8
( ) 9-15
( ) More than 15

17.) How many other elections of any type (such as local or school elections) have you voted in?
( ) None
( ) 1-8
( ) 9-15
( ) More than 15

18.) What states have you voted in?

____

) If you have ever voted in a country other than the United States, please list the country or countries where you have voted.

____

19.) If you have voted before, describe what types of voting machines or methods you have used, and what your experience was like using them.

____

20.) Which of these voting methods did you like the best? Which of these voting methods did you like the least? Why?

____

21.) Over the last 10 years, many jurisdictions have switched from an older voting technology to digital, computerized voting systems. Do you feel this change has been beneficial to you as a voter? Why or why not?

____

22.) If you had previously voted as a sighted person, have your voting habits changed? How?

____

23.) How do you get to the polling station?

____

24.) Have you ever received assistance during the actual process of voting and casting your ballot? If so, from whom? (Please choose all that apply)
[ ] Never Received Assistance
[ ] Family
[ ] Friends
[ ] Pollworker
[ ] Other (please specify)

25.) On average, how long does it take you from the time you enter the polling place until when you cast your ballot? (this includes waiting in line, the time to get the voting machine set up, etc)

____

26.) On average, how long does it take you to fill out and cast your ballot? (this includes only the time spent listening to instructions and making selections on your ballot)

____

27.) Are there any obstacles that you feel make it difficult for you to vote? (Please choose all that apply)
[ ] Location of the polling station

[ ] Physical layout of the polling station
[ ] Long Lines
[ ] Hours that the polls are open
[ ] No friend/family member available to help
[ ] Attitude of poll workers
[ ] Length of time it takes to vote
[ ] Other (please specify)

28.) Do you trust the poll workers to provide you with accurate information?
( ) Yes
( ) No

29.) Do you participate in early voting?
( ) Never
( ) Sometimes
( ) Usually
( ) Always

30.) How often do you review your completed ballot before casting it?
( ) Never
( ) Sometimes
( ) Usually
( ) Always

31.) How often do you cast a write-in vote?
( ) Never
( ) Sometimes
( ) Usually
( ) Always

32.) How often do you vote a straight-party ticket?
( ) Never
( ) Sometimes
( ) Usually
( ) Always

33.) If you vote straight-party, do you usually do it by:
( ) Using the single straight-party option on the ballot
( ) By voting in each race individually

34.) How do you learn about the candidates and issues?

____

35.) Have you ever had difficulty obtaining campaign documents in accessible formats?

____

36.) Have you ever felt worried about figuring out how to use the ballot or technology to cast your vote?
( ) Yes
( ) No

37.) Do you typically cast your vote on an absentee ballot?
( ) Yes
( ) No

38.) Have you ever felt that time pressure caused you to rush, make a mistake, or leave a choice blank when you would not otherwise have done so?
( ) Yes
( ) No

39.) Do you typically cast a vote for every office on the ballot?
( ) Yes
( ) No

40.) When you voted in an election, have you ever been unsure if your vote was cast correctly or would be counted? If yes, please describe the situation.

____

41.) Some voting machines let you use both visual and audio modes while you vote. Would you prefer to use both modalities while you voted?
( ) Yes
( ) No

42.) Would the ability to change any of the following increase your likelihood of using the visual mode in addition to the audio? (You may choose more than one answer)
[ ] Increase Font Size
[ ] High contrast display
[ ] Other screen adjustment (please specify)

43.) If it were available, would you prefer to use a Braille interface instead of an audio interface?
( ) Yes
( ) No

44.) Please rate your level of proficiency on a scale of 1 to 10, with using a telephone keypad to enter numbers (With 1 meaning "I've never used it", and 10 meaning "I'm completely proficient")
( ) 1
( ) 2
( ) 3
( ) 4
( ) 5
( ) 6
( ) 7
( ) 8
( ) 9
( ) 10

45.) How comfortable would you be with using a telephone keypad to control your interactions with a voting machine?
( ) Very Comfortable
( ) Comfortable
( ) Neither Comfortable or Uncomfortable
( ) Uncomfortable
( ) Very Uncomfortable

46.) How comfortable would you be with using a direction keypad (four arrow keys, giving you the options of up, down, left, and right) to control your interactions with a voting machine?
( ) Very Comfortable
( ) Comfortable
( ) Neither Comfortable or Uncomfortable
( ) Uncomfortable
( ) Very Uncomfortable

47.) How important is it to you that you have a way of directly verifying that your ballot accurately represents how you intended to vote?
( ) Not important
( ) Somewhat important
( ) Very important
( ) Essential

48.) In general, would you prefer a voting machine's audio interface to use
( ) a recorded human voice
( ) a synthesized voice from text-to-speech software

49.) What gender voice would you prefer?
( ) Male
( ) Female
( ) No Preference

50.) Please rate your level of familiarity and comfort with using and understanding synthesized voices (With 1 meaning "I've never used it", and 10 meaning "I'm completely proficient"):
( ) 1
( ) 2
( ) 3
( ) 4
( ) 5
( ) 6
( ) 7
( ) 8
( ) 9
( ) 10

51.) Which of the following would you like to be able to adjust on an audio interface? (Please choose all that apply)
[ ] Speed
[ ] Volume
[ ] Pitch
[ ] Language
[ ] Other (please specify)

52.) Is there anything else you'd like to add? This could include any opinions your have on the existing voting systems, experiences you've had or heard about while voting, or suggestions for us on how to improve existing voting technology.

____

Additional Questions Given in Person:

53.) Would you like the buttons to be
___Bigger
___Smaller
___This size is fine

54.) How easy would you say it is to discriminate between the buttons and tell which one is up, down, left, right, etc?

___Very Easy
___Easy
___Average
___Difficult
___Very Difficult