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Accessible Voting Technology: Analysis and Recommendations

Deb Cook, University of Washington

Mark Harniss, University of Washington

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The Information Technology and Innovation Foundation
1101 K Street NW, Suite 610
Washington, DC 20005
(202) 449-1351

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EXECUTIVE SUMMARY

This manuscript is a high level analysis of the usability and accessibility of accessible, electronic voting systems currently in use in the United States, along with guidance about developing increasingly accessible and usable systems. The discussion is based on review of the Voluntary Voting System Guidelines (VVSG Draft 1.1) developed in 2007, review of relevant standards and guidelines (e.g., Section 508 of the Rehabilitation act of 1973 as amended), and observation of past, present and prospective future voting systems. The primary purpose of this review is to inform guideline developers, voting system manufacturers, election officials and citizens with disabilities about successful strategies along with issues and concerns related to accessibility of voting systems in general. It is not meant as a review or rating of any particular system or implementation. In fact, some of the voting systems considered in this analysis were developed prior to adoption of VVSG 1.0 in 2005 and thus cannot be expected to fully comply with the standards.

The VVSG requirements are organized by disability. We have chosen instead to organize this discussion using functional feature groupings based on operability, adjustability, discernibility, understandability, and usability testing. For each functional category, we describe the associated VVSG requirements, describe their purpose, provide analysis about the extent to which requirements are being met in current or proposed voting systems, and offer recommendations for improvement of the requirements and implementation strategies.

Voting systems in this evaluation generally met HAVA accessibility requirements to the extent they were required to do so. The requirements, however, are based on particular disability groups such as blindness, low vision, manual dexterity, etc. and do not take into account combinations of disability. This results in requirements that may work well for people who are blind but not for people who are blind with limited dexterity or limited tactile sensitivity. As might be expected, stand-alone systems designed after implementation of VVSG 1.0 have a much greater compliance than those designed prior to VVSG 1.0. Ballot preparation systems based on laptops or tablets generally do not comply with the VVSG requirements and are not currently expected to do so despite the fact that they are being increasingly used as part of the voting process.

Usability of accessible voting systems has also improved overall since passage of HAVA in part due to development of the VVSG requirements and also due to an increased focus on usability by voting system developers. Despite this progress, some recurring issues continue to affect accessibility and usability of voting systems by people with disabilities including:

- Lack of synchronization between formats in multimodal presentation (text and audio output);
- Lack of implementation of context sensitive help and failure to use plain language;

- Inconsistent methods between systems for accessible ballot verification which potentially results in confusion for voters if they use more than one voting system over time;

- Inconsistent design and function between systems in the operation of accessible controls and keys. For example, there is no standard way of moving through contests or choices. Some systems move horizontally through contest while others move vertically through them;

- Ineffective methods for entering write-in choices resulting in potential confusion for voters with cognitive or language limitations.

Our broad recommendations include the following:

- We recommend a functional approach to the presentation of voting accessibility requirements with established performance benchmarks rather than one focused on disability groups as likely to be more effective in assuring usability of systems for the widest range of people. Focusing on the potential limitations of disability rather than focusing on the functional requirements of voting may lead to an expectation that voting system developers must also be disability experts. On the other hand, it is reasonable to expect voting system developers to understand and comply with specific functional requirements and to implement a range of creative solutions for functionally based problems such as those associated with discerning ballot content and instructions, manipulating voting mechanisms, etc.

- We recommend that there be a few solutions that accommodate as many people as possible by the simplest means as most cost effective and efficient rather than a broad variety of solutions that accommodate specific disability groups. Most of the ballot preparation approaches, based on laptops or tablets, for example, accommodate people who are blind reasonably well but may be completely unusable for people who lack English proficiency. This problem can be resolved at the system design level by thinking about the functions of voting rather than about people with a specific disability such as blindness or lack of dexterity.

- We recommend that a broader range of individuals with disabilities including individuals with intellectual or learning limitations, individuals who are deaf, those who lack English proficiency, and individuals with dexterity and physical limitations be considered in usability and accessibility testing in order to capture the true range of voter needs. Individuals with combinations of disabilities such as deaf-blindness or limitations associated with aging such as lack of dexterity combined with vision loss must also be considered in usability and accessibility testing because the impact of having more than one functional limitation is often greater than accommodating one factor. For example, a person who is blind and has limited tactile sensitivity may have difficulty feeling tactile labels if there is not distinct tactile contrast created by height, shape and texture. A person who is deaf-blind will need some means other than an audio ballot, such as a braille display, in order to interact with the voting system. A voter with low vision who

has cognitive limitations due to aging may have difficulty remembering the non-visual cues such as the unique shapes of controls or keys.

- We recommend that standards should be developed to address the use of laptops and tablets as voting systems or ballot preparation systems. Accessible voting systems based on emerging technologies, tablets and laptop computers are promising, but developers must not rely on features of off-the-shelf systems (e.g., browser settings,) which may work well but may not be known to voters and poll workers. Instead, settings that allow the voter to control the presentation of information must be readily available within the voting system itself.

INTRODUCTION

People with disabilities are less likely to be employed, have lower education levels, are less likely to be registered voters, and are more likely to be elderly (National Council on Disability, 2010). There are a variety of both existing and emerging assistive technologies that can be used to enhance the employment, education and independent living opportunities for many individuals with disabilities. Unfortunately, (unless it is part of an education, employment or medical accommodation), people with disabilities often have less access to technology in general, are familiar with a smaller range of technologies, and for some disabilities, may have little experience with using technology (with or without assistive technology) for the functions needed for voting. Therefore, it should not be assumed that voters with disabilities arrive at the polling place with a consistent set of technology skills that can be used as the basis for evaluating usability. Voting is an occasional process at best. The elections technology, the expertise of poll workers in supporting voters in using the technology to vote, and election processes vary widely among voting jurisdictions. This lack of consistency between jurisdictions can create confusion for voters and exacerbate the challenges faced by voters with disabilities. To increase the rate of successful voting experiences, voting technologies need to be adjustable, easy to operate, and compatible with technologies that voters with disabilities already know and use. In addition, instructions and content must be readily discernible and easy to understand. In short, voting systems should be usable by individuals with a wide range of skills, abilities and experiences.

Any voter who can perform the functions needed to vote, with or without assistive technology, should be given the opportunity to vote independently. Although even the best designed system may not be usable by some people with disabilities under some conditions, voting systems should be developed that address as wide an audience as possible.

HOW WE CONDUCTED THIS REVIEW

In this manuscript, we provide a high level analysis of key usability and accessibility factors along with guidance about developing increasingly accessible and useable electronic voting systems. Our discussion is based on review of the Voluntary Voting System Guidelines (VVSG Draft 1.1); review of relevant standards and guidelines (e.g., Section 508 of the Rehabilitation act of 1973 as amended); and informal observation of past, present and prospective future voting systems. Specifically, our findings were informed through an expert review of accessible voting systems conducted at the National Federation of the Blind (NFB) and the National Institute of Standards and Technology (NIST) as well as conversations with multiple vendors of current and prototype voting systems. Appendix A includes a list of the voting systems reviewed at NFB and NIST and Appendix B contains a list of voting system vendors that were interviewed. These systems included the range of voting systems that are now or have been in use in U.S. elections including DREs, ballot marking devices, browser

applications used on laptops or tablets for ballot preparation, and vote by phone systems. Some of the voting systems considered in this analysis were in use prior to adoption of VVSG 1.0, established in 2005, and thus cannot be expected to comply with the requirements.

The VVSG 1.1 draft guidelines developed in 2007 were used rather than the released 1.0 Guidelines to structure the discussion because they provide more detailed guidance, represent current thinking regarding accessibility, and include relevant discussion regarding how the guidelines relate to usability.

The primary purpose of this review is to inform guideline developers, voting system manufacturers, election officials and citizens with disabilities about successful strategies along with issues and concerns related to accessibility of electronic voting systems. It is not the purpose of this document to review specific systems or evaluate their individual accessibility in any way. Our analysis represents the accessibility and usability perspective. It is not intended as a legal analysis.

A FUNCTIONAL ANALYSIS OF VOTING SYSTEMS

The VVSG requirements are organized by disability type; however, we have chosen to organize our discussion using five functional feature groups that include operability, adjustability, discernibility, understandability, and usability. By focusing on broad functional categories, we are able to show how changes in these categories can improve accessibility across types of disabilities. This matches with the analysis conducted in the AVTI Working Paper #002 conducted by another project member (McGrew, 2012), which focuses on voting tasks and types of assistive technologies that facilitate access for each of those tasks. The tasks delineated in that paper cut across the functions described in our paper and provide an illustration of how functions affect a broad range of voters with disabilities.

For each functional category, we describe the associated VVSG requirements, describe their purpose, provide analysis about the extent to which requirements are being met in current or proposed voting systems, and offer recommendations for improvement of the requirements and implementation strategies. Readers should note that meeting the technical standards laid out in the VVSG does not necessarily ensure that systems are usable in practice. We attempt to highlight situations where a system may have met the “letter of the law,” but not the intent.

OPERABILITY

Operability is the extent to which the voter is able to perform the basic operations associated with accessing the voting station, making and reviewing ballot selections, verifying the ballot accuracy, and casting the ballot.

It is the expectation under HAVA that voters with disabilities should be able to perform all functions associated with the voting process and this should be accomplished independently, privately, and accurately. Interacting with the voting system to accomplish these activities involves both entering information such as vote choices into the system (i.e., input) and receiving information such as verification of choices from the system (i.e., output). It is our experience that individuals with disabilities, like the general population, approach the voting process with a wide range of physical abilities, language skills, and technology experience.

Voters typically accomplish input and output using a visual-tactile interface such as a touch screen display. However, a multimodal approach to input and output is necessary in order to accommodate voters with a wide range of physical, sensory, cognitive, language and literacy abilities. An example of multimodal input and output interface described in the VVSG is the audio-tactile interface (ATI).

The functions associated with operability of the voting station are:

- Accessing the machine: Approach and physical space
- Initiating the voting session
- Voting input mechanisms
- Speech input
- Final verification and submission of the ballot
- Use of personal assistive technology

ACCESSING THE MACHINE: APPROACH AND PHYSICAL SPACE

WHAT IS THE PURPOSE OF THESE REQUIREMENTS?

Requirements for accessing the machine ensure that it is possible for individuals who use wheelchairs or other mobility aids to physically reach a voting system that is placed in a fixed position. This is important because these systems often lack flexibility in the placement of components such as keypads or other input devices, and displays.

WHAT ARE THE REQUIREMENTS IN THE VVSG?

VVSG 1.1 Draft requirements: 3.3.5; 3.3.5.1

Physical approach requirements apply primarily to fixed voting stations with both input controls and the output screen built into a single kiosk or arrangement of the system. These requirements are generally not applicable to voting machines with a tethered control panel and adjustable screen, systems that use the telephone, or systems that use laptops or tablets where the environment itself plays a more substantial role in ensuring accessibility of the voting system.

Figure 1: Fixed voting station

The VVSG requirements are based on the ADA Accessibility Guidelines for Buildings and Facilities (ADAAG)[1], which specify the floor space to accommodate either a forward or side approach for a voter using a wheelchair or other mobility aid, and space for an assistant to help with any aspect of the voting process if desired by a voter.

These requirements specify that labels, displays, controls, keys, audio jacks and other necessary features of the system must be both legible and visible to a voter with normal vision who uses a wheelchair and who is appropriately positioned at the voting station. Small lettering, controls and labels tilted at an awkward angle, or environmental factors such as glare from overhead lighting are mentioned as factors which could impact the voter's ability to use voting system features effectively.

The VVSG also requires that controls, keys, audio jacks and any other necessary aspects of the voting station that are necessary for its operation must be within easy reach.

HOW WELL ARE THE REQUIREMENTS CURRENTLY IMPLEMENTED?

Many of the first accessible voting machines were designed as fixed, self-contained voting stations. They were not very flexible in accommodating individual user needs. Voters with limited reach range would have difficulty reaching the controls. Voters with

[1] Available at http://www.access-board.gov/adaag/html/adaag.htm.

low vision were not readily able to adjust the focal distance of the display. Voters using wheelchairs and voters with small stature would have difficulty being comfortably positioned at the machine.

Newer systems have addressed these problems by using a variety of design approaches such as tethered keypads for data entry and screens that can be more readily adjusted for height and distance. These newer units more readily fit into a variety of traditional and non-traditional voting environments and accommodate a wide range of individual user needs related to mobility, dexterity and vision. Newer features include a tactile keypad that can be positioned in a variety of ways such as on a table, on a wheelchair table or on an armrest, and use of a swivel arm to position the screen for best focal distance and viewing without straining the neck upward.

RECOMMENDATIONS

1. Make voting systems portable with adjustable or free standing screens and tethered rather than kiosk-style systems with fixed positions of the control panels. This will help ensure accessibility for the widest number of voters. Voters who must lie down, for example, and voters who cannot sit in an appropriate position at a voting station could also benefit from a future voting system based on a tablet PC or laptop which could be even more flexibly positioned to meet individual needs.

Figure 2: Tethered voting system

INITIATING THE VOTING SESSION

WHAT IS THE PURPOSE OF THE REQUIREMENTS?

Some voting systems must be activated for each voter, often by an action initiated by the voters themselves, such as inserting a card or other device into a slot somewhere on the system. This might mean being able to locate and identify where to insert the voter activation card or a ballot and ensuring that it is inserted correctly on a hardware

voting system. On a telephone, laptop, or tablet used for voting, it might mean obtaining an activation code in an accessible format and a means of accurately entering and verifying that code.

To initiate a voting system independently, voters must be able to find the location for any activation device, and insert it accurately.

Clear tactile and visual markings on voting activation cards along with clearly labeled and easy to reach card slots benefit all voters, but are particularly important for blind voters and voters who may have difficulty understanding instructions due to cognitive limitations or lack of English proficiency.

Voters who have limited hand dexterity or who lack coordination need card activation mechanisms that are easy to manipulate.

Voters who do not possess some particular biological characteristic, such as fingerprints, need alternatives that do not require such characteristics.

WHAT ARE THE REQUIREMENTS IN THE VVSG?

VVSG 1.1 Draft requirements: 3.3.1 d.; 3.3.3 d; 3.3.4 d.

Blind voters must specifically be able to activate their own ballot if voting system features allow sighted voters to perform this action.

Controls, including insertion of an activation card or a ballot, must be operable with one hand and without excessive force. Inserting an activation card should not require much dexterity or fine motor coordination.

Finally, if fingerprints or some other form of biological characteristic is required for voter verification or authentication, then another means must be provided that does not require the particular biological characteristic.

HOW WELL ARE THE REQUIREMENTS CURRENTLY IMPLEMENTED?

None of the systems required use of biological characteristics for voter identification or ballot activation.

The other requirements apply specifically to hardware based voting systems in which physical insertion of an activation card or ballot initiates a voting session. We found that it was generally easy to correctly insert activation cards.

In some ballot marking systems we found it difficult to insert the ballot using only one hand and that it required fine finger manipulation to keep it from jamming as it entered the machine.

Some systems required entry of an activation code using the same mechanism designed for entering voting selections. This generally requires the voter to traverse the entire alpha numeric list in order to enter each character. This is especially problematic

for voters with cognitive or memory limitations who must keep track of what has been entered, what must still be entered, and how to traverse the alpha numeric list.

The VVSG requirements do not address protocols for voter identification or ballot activation when a laptop or tablet is used by the voter for ballot preparation. Voters using laptops or tablets typically must be able to type an activation or identification code in order to receive the on screen ballot and in some cases were required to complete an online form. This means the voter must know how to type, must know how to use any required assistive technologies in order to complete the form, and must be able to access all of the information required to complete the form. This process may be very difficult for people with low technology skills, limited cognitive ability, limited English comprehension or limited literacy.

RECOMMENDATIONS

1. Laptops or tablets used as voting machines should offer multiple ways of inputting any required activation information. These could include use of an alpha numeric keyboard, a keypad such as the one used for making voting selections, soft keyboard on a touch screen, etc.

2. If a paper ballot must be inserted into a printer, the mechanism should allow the ballot to be placed on a flat surface or paper-feed tray rather than inserted into a slot to accommodate one handed use.

3. As new technology is developed, there may be increased interest in use of particular biological characteristics for voter verification or ballot activation. It is important to maintain the requirement that use of these characteristics must not be the only means of performing these functions.

VOTING INPUT MECHANISMS

WHAT IS THE PURPOSE OF THESE REQUIREMENTS?

Voting input mechanisms include any controls that allow voters to navigate through the ballot, mark choices, enter write-in votes, or change system settings. They include keyboards, keypads, buttons or other hardware controls.

These requirements ensure that keys, controls and other input mechanisms are operable by individuals who lack fine motor control or use of their hands and are designed to prevent accidental activation by the voter. The requirements related to accidental activation are applicable to standard voting stations as well as to the accessible voting station. Accidental activation of controls or keys could result in voter errors and is therefore relevant to all voters.

WHAT ARE THE REQUIREMENTS?

VVSG 1.1 Draft requirements: 3.2.6 c.; 3.3.4 b.; 3.3.4 d.; 3.3.4 e.

Unintentional activation can occur if the control is overly sensitive to the touch, or if the control is located on a part of the display or keypad where it can be accidentally activated, such as near the edge where the voter might rest a hand. No key or control can have a repeat function since this could also result in unintentionally entering characters, such as when casting a write in vote.

In addition, the VVSG requires that controls should be operable with one hand, without excessive force, and must not require tight grasping, pinching, or twisting of the wrist. The combined impact of these requirements is that controls must be easily operated but not easily activated by accident. This benefits all voters but particularly benefits those who lack fine motor control.

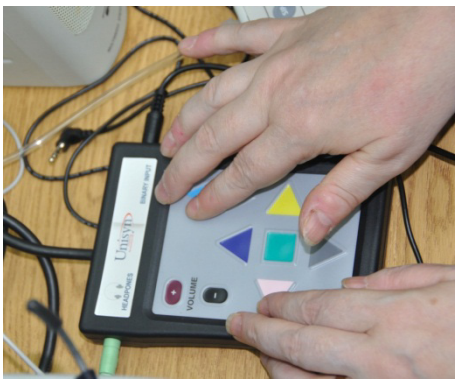

Figure 3: Input device that required significant force to operate

These requirements also say that controls should not require direct body contact or require the body to be part of any electrical circuit, as some touch-screens do. This ensures that the controls are operable by voters who use prosthetic devices.

Finally, the requirements specify that all functionality available through the conventional and tactile forms of input should also be available, with equivalent functionality, through a mechanism for non-manual input. This could be achieved, for example, using a switch device with a mouth stick or sip and puff to activate particular controls.

HOW WELL ARE THE REQUIREMENTS CURRENTLY IMPLEMENTED?

Input mechanisms on all of the dedicated voting systems were designed to prevent accidental activation. They did not repeat functions when controls were pressed for a longer than normal duration. All of the input mechanisms on the dedicated systems could also be operated with one hand. None of the input mechanisms utilized direct body contact as a means to operate the system.

One fixed voting station had a very stiff input mechanism with little key travel and needed significant pressure to activate the controls. This responded to the requirement

for preventing accidental activation, but resulted in controls that were difficult to manipulate for users with limited dexterity.

Another voting system utilized a wheel to select among choices with an associated key to enter selections. It was not likely that voters would enter choices accidentally but it was easy to accidentally skip options or stray into a different contest because the wheel rotated freely, with very little resistance.

On the dedicated voting systems, the switch input mechanisms for operating controls did not provide equivalent functionality when compared to the keypads and other tactile input solutions. The most effective examples of tactile input mechanisms include two unique sets of controls that allow the voter to discretely move between contests or between choices within a contest. This makes it possible to easily skip contests if desired. This was implemented in a variety of ways, such as controls shaped as vertical arrows or triangles to move within a contest and horizontal controls to move between contests. The switch input mechanisms, on the other hand, generally allow navigation only in linear fashion through the ballot from start to finish, and require the voter to traverse each choice in each contest with no ability to skip contests. This is largely due to design limitations of single switch devices compared with tactile keypads.

Entering a write-in vote was difficult using either the tactile keypad or a switch input device on all systems without a QWERTY keyboard. It is often cognitively challenging for users to move through the entire alphabet in a linear fashion to select each letter. If an error was made, some systems deleted the entire word while others deleted the character under the cursor. In many cases it was not clear how the deletion would be handled.

Voting systems based on laptops or tablets used standard input mechanisms commonly associated with those devices. As a result, they had controls and keys that were easy to manipulate, and met the requirement of being operable with one hand. The exception might be for individuals who use a screen reader which may require both hands in order to execute screen reading commands.

Any alternative keyboard or other input mechanism that could be connected to a laptop or tablet could be made available for use by individuals requiring alternative input devices. This allowed significant flexibility over the switch input used on the dedicated voting systems.

Laptops and tablets generally did not include safeguards to prevent key repeat or other forms of accidental key activation. This means, for example, that individuals who lack hand coordination could easily enter extra characters when entering a write-in choice. Laptop and tablet operating systems generally include an option to disable key repeat, but it is not easily accessed, is probably not known to most voters, and may not be enabled on a laptop used as a voting system in a polling place.

RECOMMENDATIONS

1. Emphasis should be placed on ensuring equivalent input functionality for switch input mechanisms used in dedicated voting systems. This means thinking creatively about options other than switch input that can be implemented both with adequate security for the system and flexibility for the voter.

2. Voting systems based on off-the-shelf laptops or tablets should be set, by default, to disable key repeat. Since key repeat is generally not controlled from the browser, it might be necessary to design a specific application for voting, based on the browser, that would also hook into the operating system to enable or disable features necessary for compliance with particular voting system requirements for input and output.

SPEECH INPUT

WHAT IS THE PURPOSE OF THIS REQUIREMENT?

The accuracy and affordability of modern speech recognition technology solutions have the potential to increase options for alternative input voting mechanisms. This requirement ensures that voter speech will not be the only mechanism available to operate a voting system.

WHAT IS THE REQUIREMENT IN THE VVSG?

VVSG 1.1 Draft requirements: 3.3.9

The VVSG simply states that voter speech shall not be required for operation of the voting system. The discussion indicates that this does not preclude voting systems from offering speech input. It does not, however, discuss factors to consider such as voter privacy, speech recognition challenges such as proper names, accents, and speech limitations due to disability if speech is offered as an option.

HOW WELL IS THE REQUIREMENT CURRENTLY IMPLEMENTED?

Currently no systems require the voter to use speech. Further, no systems that we tested are permitting the voter to use speech, although one system under development allows audible input of any kind to make a selection as one option in its multimodal interface. Use of speech input could particularly increase accessibility for individuals who have limited or no hand dexterity.

RECOMMENDATIONS

1. At a minimum, any voting system that supports speech input should allow the voter to: initiate the voting session, make ballot selections, review the ballot, perform final submission of the ballot, and get help when needed (VVSG Draft

3.1: 3.1.1). If speech is not available for all of these operations, it will probably not increase accessibility for those who would benefit.

2. Voters should encounter no difficulty or confusion regarding the process for recording their selections when using the speech input. Voters should know exactly what is necessary in order to communicate with the system.

3. The speech input must operate in a way that preserves the privacy of the voter's ballot. Voters cannot be required to say names of candidates, for example, when entering selections. In short, the voter's selections must be readily and accurately discernible by the voting system without being revealed to others.

FINAL VERIFICATION AND SUBMISSION OF THE BALLOT

WHAT IS THE PURPOSE OF THESE REQUIREMENTS?

These requirements ensure that all voters have a similar opportunity for vote verification. If the voting system generates paper ballots that are used for vote verification, they must include features, including audio verification, that specifically accommodate voters who typically have challenges dealing with reading or manipulating the paper records. This includes voters with low vision, who are blind, or who have dexterity limitations. Voters with limited literacy and voters with lack of English proficiency also potentially benefit from the requirement for audio presentation of the paper ballot.

WHAT ARE THE REQUIREMENTS?

VVSG 1.1 Draft requirements: 3.2.5 g.; 3.3.1 e. and i.; 3.3.3 e.; 3.3.4 c.

The system must have a mechanism that can read the paper vote record, and can generate an audio presentation from that paper record in English and in any other language supported by the voting system.

The voting system must include features designed to increase the legibility of the paper ballot to support voters with poor reading vision. The system could include printing in larger fonts, could support either optical or electronic magnification of the paper record, or could provide a unique method for making the paper record easier to visually read.

The system must also provide mechanisms to accommodate voters with dexterity limitations in order to perform paper-based verification or to feed their ballots into an optical scan reader. This should be done in a way that does not compromise voter privacy.

HOW ARE THESE REQUIREMENTS IMPLEMENTED?

Accessible paper ballot submission on dedicated voting systems is accomplished by attaching a ballot box directly to the machine and feeding cast ballots into this box. This

is an effective solution if significant numbers of ballots are collected. However, if only ballots from voters with vision and dexterity limitations are collected in this box, there is concern that privacy is potentially compromised because the ballots might be identifiable as cast by people with disabilities.

Figure 4: Ballot box attached to voting system

Ballot verification on dedicated voting systems is generally accomplished by performing optical character recognition on the printed ballot. If this feature is built into the system, the information is potentially accessible to all voters who are unable to read and verify the printed ballot due to vision, literacy or language limitations.

Voters using off-the-shelf laptops or tablets are preparing a ballot but are not submitting the final ballot. Ballot preparation may be completed at the voter's home or other location away from the elections office, is likely to be printed and mailed or submitted directly to the elections office, and is then entered into the system. There is currently no means for ballot verification built into these systems. A particular concern for blind voters using this method is whether or not the ballot choices were printed at all. The only possible means for verification in this case is using external optical character recognition (OCR). This requires both availability of, and familiarity with such systems by the voter. Voters who are elderly or who have low income may have limited or no familiarity with OCR, and are unlikely to have access to such sophisticated technologies.

RECOMMENDATIONS

1. Significantly more research should be done regarding ballot verification for voting systems based on laptops or tablets. Developers are experimenting with online alpha numeric algorithms and other technologies that may be future solutions. The primary accessibility concerns should accommodate sensory, cognitive and dexterity abilities of the voter. Considerations include methods for how the code is transmitted to the voter, how the voter enters the verification code, and how the ballot content is conveyed to the voter.

USE OF PERSONAL ASSISTIVE TECHNOLOGY

WHAT IS THE PURPOSE OF THESE REQUIREMENTS?

Voting systems must be self-contained in order to meet security requirements, and are generally designed as stand-alone kiosks. All accessibility features must be included in the system. Most assistive technology for computer systems, however, are connected using the USB port or require that software be installed on the system. These options are not available to voters on a voting system because to do so would create a security vulnerability.

WHAT ARE THE REQUIREMENTS IN THE VVSG?

VVSG 1.1 Draft requirements: 3.3.1 c.

The VVSG says that voters cannot be required or expected to bring their own assistive technology for use with the voting system. This does not preclude voters from bringing technology that will not be interfaced with the voting system, but is normally used by the voter for mobility, seeing, hearing etc. regardless of whether or not they are voting.

Figure 5: Individual using sip and puff switch

HOW IS THIS REQUIREMENT IMPLEMENTED?

Manufacturers build assistive technology such as the audio-tactile interface and the ability to adjust various characteristics of the interface into stand-alone voting systems. Voters are generally precluded from attaching any personal assistive technology, such as a Bluetooth Braille display, due to security concerns.

Laptops and tablets used for ballot preparation may or may not include one or more assistive technology solutions. These options support a wider array of assistive technology options but there is also the increased expectation that voters will have and will know how to use a more complex array of technologies such as commercial screen readers or screen magnification.

RECOMMENDATIONS

1. In general, it should never be expected that individuals with disabilities have access to or experience with particular assistive technologies. However, to the extent that available and familiar technologies could make the voting experience more successful and comfortable, it is ideal if their use can be permitted. This is one significant advantage of the ballot preparation systems based on laptops and tablets. Security is not a primary concern since these devices do not cast a ballot. Additionally, a wide variety of technologies can potentially be connected to accommodate very specific user needs such as those of voters who are deaf blind, for example, who might require use of a Braille display in order to read the ballot and instructions.

ADJUSTABILITY

A key to accommodating the wide range of abilities and needs of voters is to offer a wide range of choices among features and settings that can easily be selected and adjusted to meet individual voter needs.

The functions associated with adjustability of the voting system interface are:

- Use of standard default values
- Font, contrast, and color adjustment
- Adjustment for language
- Audio adjustments

USE OF STANDARD DEFAULT VALUES

WHAT IS THE PURPOSE OF THESE REQUIREMENTS?

These requirements relate to the overall usability of the voting system. All voters benefit from a wide range of adjustable options, including the presentation of information, language, or choice of input devices, as well as resetting any or all settings to their defaults, which makes it easier for voters to experiment with using system features that might be beneficial to them. It is important that a voter can make a change during the voting session without losing any completed votes. For example, a voter might need different settings for ballot questions than candidate contests.

WHAT ARE THE REQUIREMENTS IN THE VVSG?

VVSG 1.1 Draft requirements: 3.2.5 b., c.; 3.3.3 c. iv.

The VVSG says that the voting system should present the same initial appearance to every voter. To achieve this, font size, color, contrast, audio volume, rate of speech, synchronized audio-video, alternative non-manual input, language, or any other setting that can be adjusted should be automatically reset to a standard default value when the voting session is completed. The standard default for volume is specifically set to between 40 and 50 dB SPL.

Additionally, there must be a mechanism to restore any values to their defaults during a voting session while preserving the current votes.

HOW ARE THESE REQUIREMENTS IMPLEMENTED?

In all cases, stand-alone voting systems returned to their default settings at the end of each voting session.

However, some of these systems did not have a way to return all settings to their defaults during the voting session. Individual settings could be adjusted, but it was not always clear how to return to the default setting. For example, the voter might return to the default volume by turning a knob until it clicked at the center, but there was not a similar technique to restore the default color or contrast. The voter would have to read the instructions again in order to reset defaults if the process is not intuitive and as consistent as possible.

Voting systems based on laptops or tablets currently require the voter to change browser settings or operating system parameters in order to adjust various settings and features. If the voter makes changes at a polling place, the laptop or tablet does not return settings to their default. The voter must also know how to make any needed adjustments within the browser or operating system which may not be intuitive, because these settings are often buried in system configuration panels.

RECOMMENDATIONS

1. Voters benefit from consistent mechanisms and processes for returning adjustable settings to their defaults. For stand-alone voting systems, the recommendation is to clearly designate default settings and make it easy to return the system to these settings at any time.

2. For voting systems based on laptops or tablets, the recommendation is to incorporate any adjustable settings within the voting application rather than depending on browser or operating system parameters for adjustment of settings.

FONT, CONTRAST, AND COLOR ADJUSTMENT

WHAT IS THE PURPOSE OF THESE REQUIREMENTS?

The basic requirements that voters be able to adjust the size and contrast of text and graphics are included in the General Usability section of the VVSG, because they are important to a broad range of voters, many of whom may not choose the Accessible Voting System.

Visual needs are widely varied. For example, voters with low vision or with cognitive disabilities often benefit from larger font sizes, high contrast or inverse colors (white text on a black background, or other color combinations). Voters with tunnel vision, on the other hand, often benefit from smaller font sizes rather than larger ones because they have a narrow field of vision.

WHAT ARE THE REQUIREMENTS IN THE VVSG?

VVSG 1.1 Draft requirements: 3.2.5 e., i.; 3.3.2 b.

All electronic displays used for voting systems must be capable of displaying information in at least two font sizes: 3.0-4.0 mm cap height, with a corresponding x-height at least 70% of the cap height and a minimum stroke width of 0.35 mm; 6.3-9.0 mm cap height, with a corresponding x-height at least 70% of the cap height and a minimum stroke width of 0.7 mm. Additional choices, including continuous variability, are allowed. The voter should be able to adjust the font size throughout the voting session while maintaining the current votes.

All electronic displays used for voting systems must be capable of displaying information in high contrast mode either by default, or by control of the voter. (High contrast is defined as a figure-to-ground ambient contrast ratio for text and informational graphics of at least 50:1.) If the contrast can be adjusted, the system must preserve the current votes. Systems may offer a low contrast option as well, but this is not required.

All color, electronic displays used for voting systems must allow the voter to adjust the display of information at any time throughout the voting session using black text on white background or white text on black background while maintaining the current votes.

HOW ARE THESE REQUIREMENTS IMPLEMENTED?

Stand-alone voting systems complied with these General Usability requirements.

Voting systems based on laptops and tablets adjust features such as font size, contrast and color using settings for the operating system or for the browser. This means these settings may not be intuitive or easy to locate if the voter is not familiar with the control panels of the operating system or of the browser.

RECOMMENDATIONS

1. Voting applications designed for laptops and tablets that are made available at a polling place should not depend on settings in the operating system or browser to meet requirements for font, contrast, and color adjustment. These settings should be available within the voting application and should be as intuitive as possible for voters to use. For example, systems could offer a pallet of examples, rather than requiring detailed setting using technical parameters.

ADJUSTMENT FOR LANGUAGE

WHAT IS THE PURPOSE OF THIS REQUIREMENT?

Regardless of their primary language, all voters should be able vote independently and privately. This is a General Usability requirement which applies to all information in the voting system (including instructions, review screens, etc.) whether presented in visual or audio format.

WHAT IS THE REQUIREMENT IN THE VVSG?

VVSG 1.1 Draft requirements: 3.2.7 a. i.

Voters should be able to switch among supported alternative languages while preserving the current votes.

HOW IS THIS REQUIREMENT IMPLEMENTED?

Stand-alone voting systems allowed voters to change language at any time throughout the voting session.

None of the voting systems based on laptops or tablets that were evaluated supported the ability to change language. This is probably not an issue if the voter is using their personal system where the default language is already in place. Setting an alternative language on a general-use computer, however, usually required both a setting in the application for the text, and an adjustment in the operating system settings to manage keyboard and display properties. This process may be particularly challenging, or even impossible, for voters or poll workers who may have difficulty reading and understanding instructions for making these changes.

RECOMMENDATIONS

1. Support for alternative languages should be implemented in any voting system that is based on a laptop or tablet.
2. Language options should be selected within the voting application rather than by making adjustments in the operating system settings.

AUDIO ADJUSTMENTS

WHAT IS THE PURPOSE OF THESE REQUIREMENTS?

The audio controls are part of the audio-tactile interface that is required to make voting accessible for people who are blind or who have low vision, and helpful to many others including individuals with cognitive or reading disabilities. Different users will choose different configurations of audio and video depending upon their needs. For example, individuals with reading disabilities will want to see the screen, read the text, and hear the audio. Individuals who are blind will only require the audio.

Many blind people are accustomed to listening to poor-quality speech synthesizers at high rates of speed as a means of reading text, and find the ability to do this while voting to be very helpful both for maintaining concentration and for completing the ballot as rapidly as possible.

The audio presentation alone, or combined with the visual presentation, is also useful for many voters who have cognitive disabilities or who lack English proficiency. The

ability to adjust various audio settings is critical to increasing the understandability of the voting process for many voters with disabilities or those who have language barriers. However, they may not have the same proficiency with audio interfaces as blind voters, so need higher-quality speech, and the ability to listen at a normal conversational rate.

The capability to adjust audio volume is important for all voters who use the audio presentation, but is particularly important for voters who are hard of hearing who may wish to raise the volume and reduce the rate of speech to increase understandability of the presentation.

WHAT ARE THE REQUIREMENTS IN THE VVSG?

VVSG 1.1 Draft requirements: 3.3.2 d.; 3.3.3 c. v., viii.

Voters must be able to adjust the presentation mode between video-only, audio-only, and synchronized video and audio, while preserving the current votes.

Voters must be able to control and adjust the volume of the audio presentation throughout the voting session while preserving the current votes. The volume must be adjustable from a minimum of 20dB SPL up to a maximum of 100 dB SPL, in increments no greater than 10 dB.

Voters must be able to control and adjust the rate of speech throughout the voting session while preserving the current votes. The range of speed must be adjustable from 75% to 200% of the normal rate without changing the pitch of the voice.

HOW ARE THESE REQUIREMENTS IMPLEMENTED?

Stand-alone voting systems supported presentation of information in video, audio, and video- audio format.

Stand-alone voting systems also allowed the voter to control and adjust both volume and rate of speech throughout the voting session. In some systems, these settings were adjusted using knobs or sliders. These particular controls had static in the mechanism which resulted in garbled speech if an adjustment was made while text was being spoken.

Some of the audio presentations were of significantly less quality when the rate of speech was adjusted to the maximum level. Adjusting speech rate without changing pitch is accomplished by shortening the vowels in words. This can result in choppy or garbled speech if a high quality synthesizer is not used or if the algorithm does not fully support this protocol.

Voting systems based on laptops or tablets used commercially available screen reading technology to provide audio output. It was possible to turn the audio on and off, adjust volume, and adjust rate of speech without affecting the pitch of the speech, but all of these changes required knowledge of the screen reader software. No instructions were provided for making any of these changes since it was presumed voters were using

their own assistive technology. This of course would not be the case if the voter comes to a central voting location where the technology is required to be provided.

RECOMMENDATIONS

1. Hardware components used on stand-alone voting machines must be durable and of high quality. Controls that do not contain moving parts, such as touch screen controls with tactile identification, may be easier to maintain in future systems.
2. Use digital human speech rather than synthesized speech, because it can generally be better understood when techniques for vowel shortening or lengthening are employed as speech rate is increased or decreased respectively.
3. Voting systems based on laptops or tablets should not rely on operating system controls or particular assistive technology product settings which may be unfamiliar to voters.
4. Mechanisms to adjust various aspects of the audio presentation including volume, rate of speed, and synchronization of audio-video should be readily discernible and easy to operate within the voting application.

DISCERNIBILITY

Voters must have adequate opportunities to receive and perceive a variety of information generated by the voting system in a timely manner. This information includes ballot content and instructions conveyed by the visual interface, the audio-tactile interface, or both. It also includes this same information presented in alternative languages, together with alternative formats, when required. In addition, voters must be able to obtain information about the controls and functions of the voting system. Of course, it is not enough for the voter to perceive output from the voting system; it must also be easy for voters to understand what is being conveyed. This section deals with how information is output to the voter.

The functions associated with discernibility of controls and information in the voting system interface are:

- Display of information
- Timing and response
- Function and status of controls and keys
- The audio interface
- Presentation of audio content

DISPLAY OF INFORMATION

WHAT IS THE PURPOSE OF THESE REQUIREMENTS?

These General Usability requirements apply to all voting systems including those not specifically designed to be accessible voting stations. They set baselines for various aspects of the visual display and information presentation in order to ensure that information is legible to as many voters as possible without the use of special adaptations. All voters who can use the visual display can benefit from clear, easy to read visual presentation of text and graphics.

The requirements for display flicker specifically protect voters from visually-induced seizures.

People with low vision or color blindness benefit from both high contrast and from color combinations that suit their individual needs. Between 7% and 10% of all men have color vision deficiencies making it infeasible to use color alone to present information.

Many individuals with cognitive limitations or reading disabilities such as dyslexia have difficulty reading serif fonts or finding information on displays cluttered with poorly formatted graphics and text or insufficient contrast.

WHAT ARE THE REQUIREMENTS IN THE VVSG?

VVSG 1.1 Draft requirements: 3.2.5 a., d., f., h., j., k.

The requirements specify several minimum standards and characteristics for voting system visual displays. The display must not use a flicker frequency between 2 Hz and 55 Hz. It must include an antiglare screen surface that shows no distinct virtual image of a light source.

Minimum thresholds are also established for display brightness, display pixel pitch, display area, and ambient contrast. The minimum figure-to-ground ambient contrast ratio for all text and for all icons that convey information must be 10:1, providing strong contrast between the text and background. Interestingly, this contrast ratio requirement is more stringent than other guidelines (e.g., WCAG 2.0 requires 4.5:1), thus ensuring that a broader audience can be included.

The VVSG recommends that text be presented in a sans serif font. It is required that the height of capital letters be at least 3.0 MM, other text must be at least 70% of cap height, and stroke width must be at least 0.35 MM.

The recommended color combination for standard information is black text on a white background, reserving color for special cases such as warnings or alerts. Color can never be used as the sole means of conveying information, indicating an action, prompting a response, or distinguishing a visual element, but must be combined with a unique shape or other distinguishing feature.

Colored text on a colored background may not be used: either the text or background must be either black or white. There are additional requirements based on the choice of black or white as either the foreground or background color.

The specific needs of individuals who are color blind must be considered in selection of the default color coding. This would include high luminosity contrast, use of uniquely shaped icons used with color coding, and avoiding red-green color combinations.[2]

HOW ARE THESE REQUIREMENTS IMPLEMENTED?

Only voting systems specifically designed for accessibility were reviewed. All of the stand-alone systems fully met these requirements.

Laptops and tablets used for ballot preparation generally met these requirements because they used default browser and system settings. Browsers do not necessarily return to their default settings between sessions, however, so it may be difficult to ensure maintenance of optimal display settings between voting sessions at a polling place.

[2] For additional guidance see “NISTIR 7537: Guidelines for Using Color in Voting Systems” available at http://vote.nist.gov/NISTIR-7537.

RECOMMENDATIONS

1. Ballot preparation applications designed for laptops and tablets should include features that ensure compliance with voting system General Usability requirements for text and display properties. These ballot preparation systems are currently not covered by the VVSG although they are being increasingly used as part of the voting process for a wide range of individuals both with and without disabilities.

TIMING AND RESPONSE

WHAT IS THE PURPOSE OF THESE REQUIREMENTS?

These General Usability requirements describe how the voting system will interact with the voter in a responsive manner. They provide reassurance to the voter that the system is responsive and operating correctly. For voters with cognitive limitations or who lack English proficiency, this responsiveness can be especially helpful if the voter is not comfortable with tasks to be performed or with operation of the machine.

They also ensure that the system does not “time-out,” cutting off access for voters whose interaction with the system is slow, making them unable to respond quickly to prompts.

WHAT ARE THE REQUIREMENTS IN THE VVSG?

VVSG 1.1 Draft requirements: 3.2.6.1

Systems must respond to voter input, in both the audio and visual interfaces, within 0.5 seconds.

When the voter performs an action to record a vote, the complete system response time is required to be no greater than 1 second for a visual system and 5 seconds for an audio system. More time is allowed for audio systems because of the varied amount of time required to orally read relevant information.

The system response time for the visual voting system is required to be no greater than 10 seconds, even for long operations such as initializing the ballot or painting a new screen. There is no requirement for audio systems because there is no way to predict the length of time that might be necessary for audio presentation of information.

If the visual voting system has not completed its visual response within 1 second, it must give the voter some indication that it is working within 0.5 seconds of the voter’s action. There is no similar requirement for the audio system.

Each voting system is required to have a defined and documented time of allowable inactivity between two and five minutes. When the voter inactivity time has expired, the system must alert the voter, and must provide a way to extend the time between 20 and

45 seconds. If the voter still does not respond, the system is required to go into an inactivity mode.

HOW ARE THESE REQUIREMENTS IMPLEMENTED?

Stand-alone voting systems designed after VVSG 1.0 was adopted generally comply with these requirements. Some systems designed prior to 2005 were not compliant regarding response to inactivity. One system repeated instructions over and over, and one did not time out at all over an extended period of inactivity.

Timing and responsiveness may not be as relevant for ballot preparation systems using laptops or tablets. If the ballot form is on the device, the appropriate response time should be based on the device and its normal operation.

If the ballot is online, the system cannot control speed with which the ballot is downloaded to the local device. Since these systems are used only for ballot preparation and not for ballot submission, there is likely to be less voter concern regarding system unresponsiveness and integrity of the voting experience.

The VVSG requires that visual voting systems indicate that action is occurring if the system is unable to meet response requirements. This may be accomplished using a scroll bar or other indicator. This requirement does not currently apply to audio systems.

RECOMMENDATIONS

1. Audio systems should provide an audible progress indicator if there is a system delay in responding to a request. A short, periodic tone is adequate for this indicator.

FUNCTION AND STATUS OF CONTROLS AND KEYS

WHAT IS THE PURPOSE OF THESE REQUIREMENTS?

Blind voters and those with low vision need mechanisms that allow them to determine the status and function of keys and controls throughout the voting interface without accidental activation and unwanted results.

This requirement for identification of the state of controls is also potentially useful to voters who have cognitive limitations, voters with limited dexterity who are using the tactile interface, and voters with limited English proficiency.

WHAT ARE THE REQUIREMENTS?

VVSG 1.1 Draft requirements: 3.3.2 c.; 3.3.3 f., g.

Buttons and controls on accessible voting stations, whether tactile or on screen, must be distinguishable by both shape and color. This requirement is not applicable to large

groups of controls such as a telephone keypad or standard typing keyboard, where the position of individual keys within the keyboard provides a secondary indication of their function.

Controls, keys and other hardware interfaces must allow voters to find and identify them tactilely without activating them. It also must not be possible to activate the controls or keys unintentionally.

The status of all keys or controls that can be locked or toggled must be visually discernible and also must be discernible through touch or sound.

HOW WELL ARE THESE REQUIREMENTS IMPLEMENTED?

There was a significant variance among stand-alone voting systems regarding implementation of tactilely discernible controls and keys.

In our observations, an interface that has been well received by voters uses raised keys with distinct shapes such as triangles pointing in different directions, a circle and a diamond. We also noted, however, that a significant number of voters who were blind from childhood and voters with mild cognitive limitations were uncertain as to what the term “diamond-shaped” meant and used a process of elimination to determine which key was applicable.

Another voting system had large, uniquely shaped controls which were very flat. These controls are more difficult for voters with limited tactile sensitivity to distinguish by shape because they do not extend above the surface enough.

Another system used a numeric keypad for the voting interface, using the layout of a telephone keypad, with 1, 2, and 3 on the top row. This layout is reverse of the numeric keypad on computer systems and calculators, where 1, 2, and 3 are on the bottom row. Although the familiarity of a numeric keypad makes use of common interfaces, the degree to which this interface is intuitive depends on the voters’ experiences. It may be cognitively difficult to use a telephone keypad layout if the voter expects a computer-style layout. Systems generally did not use locking or toggle controls.

Braille provided tactile labeling for keys and controls. This works extremely well for voters who are knowledgeable regarding Braille. It also works for many other voters with vision loss who have basic familiarity with the Braille alphabet. Of course, it does not assist voters who do not know Braille at all and also cannot read the print labels. These voters must depend entirely on audio cues such as repeated references to the shapes and colors of various controls.

The choice of using either audio or tactile indicators may make the systems difficult for people who have both vision and hearing loss (e.g., such as age-related vision and hearing loss).

Ballot preparation systems using laptops or tablets relied entirely on the keyboard or touch screen interface of the device. If voters know how to use the available input

method, no additional labeling is required. Voters who are unfamiliar with laptop or tablet controls would find this lack of labeling to be very inadequate.

RECOMMENDATIONS

1. Tactile shapes used to identify controls or buttons should be very familiar without verbal description that includes a visual reference. Circle, square, triangle etc. are more familiar than diamond, heart, bell shapes.

2. Shapes that are slightly elevated above the surface of the display are more readily identifiable for individuals who have nerve damage in their hands or other reduced tactile sensitivity. This recommendation matches requirements in the new 2010 ADA Standards addressing ATM accessibility that require that “At least one tactilely discernible input control shall be provided for each function. Where provided, key surfaces not on active areas of display screens, shall be raised above surrounding surfaces. Where membrane keys are the only method of input, each shall be tactilely discernible from surrounding surfaces and adjacent keys.” (2010 ADA Standards; 701.61 Input Controls).

3. In addition to Braille, consider adding raised lettering to key labels, where there is space on or near the key. This might better meet the requirement that keys and controls be identifiable without activation.

4. The status of locking or toggle controls should be indicated visually, and with both audio and tactile confirmation to assist voters who have both hearing and vision loss.

5. Ballot preparation systems using laptops or tablets should include clear indications regarding keystrokes or touch areas of a screen.

Figure 6: Clearly defined buttons (i.e., with distinct shapes, easily discernible from the background visually and tactilely, shapes are logical)

THE AUDIO INTERFACE

WHAT IS THE PURPOSE OF THESE REQUIREMENTS?

The audio presentation is part of the audio-tactile interface, making ballot and related instructions available for those who cannot read standard print or who cannot readily understand written languages supported by the voting system. This includes people with blindness or low vision, people with limited literacy, people who have cognitive limitations associated with reading or comprehension of written materials, and people with limited English proficiency.

Some voters will use the audio presentation in combination with the visual presentation in order to increase understandability of the content. These requirements can be particularly helpful to voters, such as the elderly, who often have both low vision and moderate hearing loss.

There is currently no requirement to make voting accessible for people who are both deaf and blind. It is currently expected that the voter can either read print or hear audio.

WHAT ARE THE REQUIREMENTS?

VVSG 1.1 Draft requirements: 3.2.3.1 c.; 3.3.3 c.; 3.3.6; 3.3.7

Voting systems that include presentation of an audio ballot, or that otherwise provide support for audio, are required to do so in a usable way.

The voting system is required to have an industry-standard 3.5MM stereo headphone jack for private listening.

Telephone-style handsets or headsets that are used to present audio must include a wireless t-coil coupling for assisted hearing devices that achieves at least a category T4 rating as defined by [ANSI01] American National Standard for Methods of Measurement of Compatibility between Wireless Communications Devices and Hearing Aids, ANSI C63.19. Additionally, no voting device should emit electromagnetic interference that would substantially disrupt the performance of hearing aids or cochlear implants.

A sanitized headphone or headset must be available to each voter. The headphone must be of sufficient quality to prevent audio leakage at high volume levels in order to ensure voter privacy.

If the accessible voting system provides sound cues to alert the voter, the tone must be accompanied by a visual cue, unless the station is in audio-only mode.

The audio system must support frequencies over the audible speech range of 315 Hz to 10 KHz which includes the range of human speech.

The audio presentation of information generated by the system should be understandable for voters who have normal hearing and are proficient in the language.

This includes proper enunciation, normal intonation, appropriate rate of speech, and low background noise. This does not cover audio presentation developed by local election officials.

HOW WELL ARE THE REQUIREMENTS CURRENTLY IMPLEMENTED?

All stand-alone voting systems and PC or tablet based ballot preparation systems included a standard hardware jack for use with headphones. It was not always easy to reach and locate the hardware jack. In general, we found that older machines tended to place the hardware jack in places that were more difficult to find while newer machines showed improvement.

None of these systems required use of a telephone handset.

All of the systems were able to reproduce frequencies over the entire audio speech range. There was a significant quality difference between audio systems that used digitized speech compared with those that used synthesized speech. Generally digitized speech is easier to understand for individuals who are unfamiliar with the content or who lack experience using an audio presentation. These individuals include the elderly, those who lack English proficiency, and individuals with low literacy or limited cognitive skills.

In one instance, a voting system used an inexpensive speech synthesizer that does not pause for punctuation when reading long passages of text such as a ballot measure. This may not be a problem for some blind people who are experienced with using low quality synthesizers at fast rates of speed, but would be a significant problem, for example, if a voter with limited English proficiency is using synchronized audio and video to assist in understanding the ballot language.

Another system used high quality digitized speech to read the ballot template and prompts, but used a human speaker to say candidate names and read ballot measures. There was a significant difference in volume and quality between the digitized template and the candidate names, and there was background noise during the reading of candidate names. This distraction may make the audio presentation difficult to comprehend for voters who have low vision along with a hearing loss or who have cognitive limitations.

RECOMMENDATIONS

1. The discussion suggests it may be acceptable to provide throw-away headphones for voters who use the audio ballot. Such headphones often permit audio leakage and may negatively impact voter privacy. A better solution is to provide a high-quality headset with replaceable, sanitized ear covers to ensure that sound does not leak at higher levels.

2. Digitized speech rather than synthetic speech should be used for voting system audio. Implementing digitized speech is significantly easier and less expensive

than it was when audio voting systems were first initiated. Although many blind people, who use synthesized audio extensively for reading, find synthesized speech to be more responsive at high rates of speed than digitized speech, most other individuals are better able to understand higher quality digitized speech with human inflection.

3. If ballot content is read using recorded human speech, it is important to ensure that sound quality and volume levels are consistent for the human speech used for ballot content and the digitized speech used in the ballot template.

4. Future voting systems must provide better access for the increasing number of voters who are deaf-blind. Video relay and Braille display technologies are increasingly viable options to supplement the audio-tactile interface. Use of these technologies is possible for the ballot preparation systems based on lap tops and tablets, but should also be incorporated into stand-alone voting systems.

PRESENTATION OF AUDIO CONTENT

WHAT IS THE PURPOSE OF THESE REQUIREMENTS?

These requirements ensure that the audio produced by the system presents instructions, ballot options and choices made by the voter in an understandable manner.

They also ensure that voters with low vision, low literacy, low English proficiency or other cognitive limitations can benefit from audio content suitable for people who do not use an audio-tactile interface routinely. These voters particularly benefit from synchronized audio and video, the ability to have text repeated, and the ability to pause and resume the audio as needed.

WHAT ARE THE REQUIREMENTS IN THE VVSG?

VVSG 1.1 Draft requirements: 3.2.3.2 b.; 3.2.7 a.; 3.3.1 b.; 3.3.2 d.; 3.3.3 b.; 3.3.7 a.; 3.3.8

The accessible voting system must be capable of presenting an audio format ballot that supports full functionality of the visual ballot interface including instructions and feedback on: initial activation of the ballot; how to operate the accessible voting station; navigation of the ballot; contest choices including how to enter write-in candidates; confirming and changing votes; and final submission of the ballot.

The audio format must be available in any language, whether written or spoken, supported by the voting system.

The cast voter record should have no indication whether a voter used any accessibility feature of the system.

Systems must have the capability to provide synchronized audio output of information that is displayed on the screen.

The audio system must allow the voter to: have any information provided by the system repeated; pause and resume the audio presentation; skip to the next contest or return to previous contests; interrupt reading and respond immediately.

HOW WELL ARE THE REQUIREMENTS CURRENTLY IMPLEMENTED?

All of the stand-alone voting systems provided an audio format ballot for languages supported by the system. A review of other languages with native speakers indicated that translation was accurate although digitized speech had better pronunciation than the software synthesizers.

Ballot preparation systems based on laptops and tablets are capable of supporting languages other than English but no ballot samples for languages other than English were available for testing. In some cases, special configuration is necessary for commercial screen readers to accurately process other languages. This level of technical assistance might not be readily available at the voting site.

Several incorrect assumptions were made with the design of early accessible voting systems. It was assumed these systems would be used exclusively by voters who were blind and that the voters would never need synchronized audio and video. The audio presentation was often markedly different from the visual presentation. As accessible voting technologies have matured, synchronized audio and video have become more important and there is greater understanding that the potential audience, including many people with low vision, can benefit from synchronized text and audio ballot presentation. Only one system in the evaluation had text and audio that did not match closely.

Voting systems generally reproduced all content including instructions, ballot content, warnings and error messages in the audio format. Presentation of information and use of language is further discussed in the section on Understandability.

Entering a write-in vote is an example of where audio is not consistent. Some voting systems only read back each letter as typed with no way to verify what has been entered thus far, others read all letters entered up to that point as each letter is added. Both methods potentially result in cognitive confusion for some voters regarding what letters have been entered and correcting errors.

RECOMMENDATIONS

1. As voting systems move to laptops and tablets, attention is needed to ensure audio presentation support for languages other than English, supporting the requirements that the voter be able to switch among available languages without losing the current votes.

2. Research regarding options for entering write-in choices is recommended. Only voting systems based on laptops handled this well. Using a keyboard requires that the voter have QWERTY typing skills which is not necessarily the case for many voters. Voting systems need methods for entering and editing write-in choices which are reliable, accurate and easy to use.

UNDERSTANDABILITY

A voting system can be discernible, operable, adjustable and perceivable by voters with disabilities, and still not be an effective system if it is not intuitive to use and clear to read and understand. Developers and purchasers of voting systems must also pay attention to cognitive aspects of usability and accessibility, which we refer to as understandability.

In the VVSG 1.1, understandability is addressed in several parts, in both the usability section (cognitive and interaction) and accessibility section (cognition and English proficiency). These requirements are intended to reduce cognitive difficulties for all voters, not just those with disabilities. The guiding principle in these requirements is that voters should understand how to operate the voting system and understand the effect of any actions they take.

The functions associated with understandability of the voting station are:

- Availability and clarity of instructions
- Ballot design
- Accessing help
- Alerts and warnings
- Plain language

AVAILABILITY AND CLARITY OF INSTRUCTIONS

WHAT IS THE PURPOSE OF THESE REQUIREMENTS?

These requirements are intended to ensure that all people (with and without impairments) can understand how to use a voting system. However, they are especially important for individuals with cognitive disabilities and for people with limited English language proficiency who often include, for example, voters who are deaf and use American Sign Language.

WHAT ARE THE REQUIREMENTS?

VVSG 1.1 Draft requirements: 3.2.4 a; 3.2.4 c; 3.2.4 c. iv; 3.2.4 e. iv

These requirements identify when instructions are required and the approaches to giving instructions that result in greater clarity for voters. Specifically, these requirements state that any valid action that a voter could take on a voting system must be documented and instructions for how to perform the action must be available.

All instructions must be written in plain language using common, familiar words. Instructions also need to be clearly structured so that conditional phrases start with the condition and then the action to be performed (e.g., “in order to change your vote, do X”).

Individual instructions need to be separated spatially from other instructions, but should be close to the specific sections where the action they explain takes place. Finally, the instructions should be written in direct, active language not in passive, negative language (i.e., tell the voter what to do, not what not to do).

HOW WELL ARE THE REQUIREMENTS CURRENTLY IMPLEMENTED?

More contemporary voting systems provide instructions in a clearer fashion than older systems, so it appears that approaches to providing instructions are improving.

Many systems provided extensive instructions up front, before the start of voting. For example, systems would have one large set of instructions at the beginning that tell a voter how to cast a vote, change a vote, move forward a screen, and so on, but not at the time a voter needs to engage in the action. Voters must remember the instructions as they progress to vote.

Some systems used inconsistent language to describe the same thing. For example “Welcome to the *visually impaired ballot*. Please be methodical and patient when using the *audio ballot*.”

Many systems included terms that are not in common use. For example, “If you wish to confirm your desire to *undervote* you can continue on to the next contest by pressing the right arrow key.”

In the audio version of instructions, some systems did not have a mechanism to allow voters to skip redundant or unnecessary instructions and required voters to listen to all instructions even when they did need them.

One system had written instructions that did not match the audio instructions. Although this might not matter for voters who cannot see the text on the screen, it would be problematic for voters with cognitive and reading disabilities who may listen to audio while trying to read the screen.

RECOMMENDATIONS

1. Voting systems should provide instructions close to the place where the action will be taken.
2. Instructions should be context sensitive and repeatable as voters move through the voting process.

3. Developers of voting systems need to review guidelines for plain language and ensure that language in instructions is clear, nontechnical, and appropriate for a diverse audience.

4. Audio instructions should match written instructions and have a mechanism for skipping forward or backward within the instructions.

BALLOT DESIGN

WHAT IS THE PURPOSE OF THESE REQUIREMENTS?

These requirements ensure that the voting system doesn't limit the design of the ballot in a way that may bias or influence voters.

WHAT ARE THE REQUIREMENTS?

VVSG 1.1 Draft requirements: 3.2.4 d; 3.2.4 e. i-iii

Guidelines for ballot design can be found on the EAC website.[3]

The requirements for ballot design in the VVSG 1.1 do not provide guidance about ballot design, but focus on ensuring that a voting system has mechanisms to allow for ballot design that does not introduce bias for or against contest choices.

Systems must allow presentation of candidates (both visually and aurally) in an equivalent manner.

They must have adequate capacity to allow for the design of a clear and comprehensible ballot that is not visually presented across two pages or columns, that clearly indicates the maximum number of candidates for which one can vote, and that ensures there is consistency in the relationship between the name of a candidate and the mechanism to use vote for him or her.

HOW WELL ARE THE REQUIREMENTS CURRENTLY IMPLEMENTED?

Voting systems generally presented choices in equivalent fashion within and across contests. In addition, the audio and visual presentations generally matched when presenting contests.

In contrast to the VVSG requirements, many systems did present contests across multiple columns, which can increase confusion for screen reader users; however, none presented contests across multiple pages.

[3] See "Designing Polling Place Materials" available at http://www.eac.gov/election_management_resources/designing_polling_place_materials.asp.

The interface of one system made it easy to flip past a contest without knowing it had been missed. For individuals using screen readers, this could result in confusion about whether or not a contest had been voted or not.

In some cases, it was more difficult to differentiate where a contest began and ended, if choices and contests were presented in a linear fashion, when using the audio ballot.

We did not review the mechanisms for setting up the ballot, so cannot comment on the flexibility of systems to accommodate different designs.

RECOMMENDATIONS

1. Voting systems need to flexibly accommodate ballot designs that present races and choices in a clear, unbiased fashion.
2. To the extent possible, a single contest should be presented per page without the use of columns.
3. Audio ballots need a way to clearly differentiate the beginning and end of a contest by using different controls to navigate among contests and choices rather than presenting the ballot in a linear fashion.

ACCESSING HELP

WHAT IS THE PURPOSE OF THESE REQUIREMENTS?

Voters who get stuck when in the process of voting should be able to access contextual help without the assistance of a poll worker so they can efficiently and independently complete the voting process. This includes help with accessibility features.

WHAT ARE THE REQUIREMENTS?

VVSG 1.1 Draft requirements: 3.2.4 b

Voting systems must have a mechanism for providing context-sensitive help to voters during the voting session.

Voters should be able to get the help they need without requiring help from a poll worker.

Systems can provide access to help through a distinctive “help” button.

It is acceptable to provide written instructions separate from the ballot in addition to context-sensitive help.

HOW WELL ARE THE REQUIREMENTS CURRENTLY IMPLEMENTED?

Most systems had a way to access help. Some systems had a dedicated hardware or software help button. More contemporary systems were more likely to provide contextual help. Older systems simply routed users back to the initial set of instructions.

RECOMMENDATIONS

1. Help should be context-sensitive and specifically related to the task in which the voter is engaged.
2. Ideally, systems should implement a dedicated help button that is easy to access and is easy to remember how to use.
3. When multiple help options are available (e.g., the system does not know whether the user is having difficulty registering a vote or moving to the next page), the help system should provide the voter with a way to select the specific topic where he needs help.

Figure 7: Dedicate help key

ALERTS AND WARNINGS

WHAT IS THE PURPOSE OF THESE REQUIREMENTS?

When voters make an error (e.g., voting for too many or too few candidates, skipping a race unintentionally) they need to receive feedback from the system that allows them to fix the error. In addition, when the system is experiencing problems (failing to record votes or other system failures), it needs to notify a voter so a poll worker can be notified and potentially reboot or troubleshoot the system.

WHAT ARE THE REQUIREMENTS?

VVSG 1.1 Draft requirements: 3.2.4 c. i

When a system provides an alert or warning, it needs to be distinguishable from other information provided by the system and it should clearly state the nature of the problem and the responses available to the voter. It should differentiate user errors from system errors.

HOW WELL ARE THE REQUIREMENTS CURRENTLY IMPLEMENTED?

The systems we reviewed all alerted a voter when she under- or over-voted. However, many systems did not adequately alert a voter when she skipped a race.

Alerts often used language that was overly technical and long. For example, “You have selected fewer than the number of candidates or choices that you are permitted to select for this contest, if you wish to return to this contest and select additional candidates or choices please press the left arrow key, if you wish to confirm your desire to undervote you can continue on to the next contest by pressing the right arrow key.”

In our review, we did not experience any system errors, so cannot report on the implementation of system error alerts.

RECOMMENDATIONS

1. Alerts should be concise and clearly state the problem and how to fix it.
2. Developers of voting systems should use the results of their usability testing to determine common errors made by voters and program appropriate alerts and warnings.
3. One action that is not counted as an error in some systems is skipping a race. Voting systems should have a means for notifying voters if they skipped a race and ensure that this action was intended. This is particularly important in the audio ballot where it is easier to make an unintended skip.

PLAIN LANGUAGE

WHAT IS THE PURPOSE OF THESE REQUIREMENTS?

These requirements ensure that language generated by the system is written clearly at a level appropriate for all voters including those with cognitive disabilities, reading disabilities, and those who are not proficient in the English language, including voters who use American Sign Language for the deaf. The requirement for using plain language applies across all areas covered in this section (e.g., alerts, help, instructions) since these are system generated text, not a part of the ballot designed by voting officials.

WHAT ARE THE REQUIREMENTS?

VVSG 1.1 Draft requirements: 3.2.4 c. i-vii

All instructions need to be written in “plain language.” In federal law, plain language writing is defined as “writing that is clear, concise, well-organized, and follows other best practices appropriate to the subject or field and intended audience” (P.L. No: 111-274). The VVSG 1.1 requirements for plain language apply to elements of the voting system that are inherent or generated by default by the system and do not extend to elements of the ballot that are determined by election officials when they design the ballot.

HOW WELL ARE THE REQUIREMENTS CURRENTLY IMPLEMENTED?

As noted above, many systems do not have text that is written clearly, concisely and using simple language. Some of the text is unclear for the general population and, thus, would certainly cause problems for individuals who have difficulty accessing information from text.

RECOMMENDATIONS

1. Developers of voting systems must review guidance about writing plain language text such as “Guidelines for Writing Clear Instructions and Messages for Voters and Poll Workers” or the federal plain language site.[4]
2. Language should be user tested with a wide range of users to ensure that it is easily understood
3. Language should be tested to ensure that no language is used that can be voiced in an ambiguous way.

[4] Guidelines for Writing Clear Instructions and Messages for Voters and Poll Workers is available at http://vote.nist.gov/032906PlainLanguageRpt.pdf and the federal plain language site is available at http://www.plainlanguage.gov/.

USABILITY TESTING

It is one thing for voting systems to meet certain benchmarks and performance standards. It is also essential for these systems to actually be usable by a broad range of voters with various characteristics and experiences.

WHAT IS THE PURPOSE OF THESE REQUIREMENTS?

These requirements ensure that all voting systems are tested in realistic ways with the type of individuals who will actually use the system in real-world contexts. If manufacturers conduct systematic, thorough usability testing, they have the potential to learn about challenges experienced by voters in using the interface, understanding the instructions, and so on. This usability testing should be used in an iterative fashion to guide improvement of the voting system.

WHAT ARE THE REQUIREMENTS?

VVSG 1.1 Draft requirements: 3.2.1; 3.2.7 a.; 3.3.2 a.; 3.3.3 a.; 3.3.4a.; 3.2.8

Manufacturers are required to conduct realistic summative usability tests of their voting system using individuals who are representative of the general population. The test results must be reported to the Election Assistance Commission. In addition to the general population, manufacturers are explicitly required to conduct usability tests with people with low vision, blindness, dexterity limitations, and individuals who are fluent in supported languages other than English.

In addition to usability for voters, the VVSG also requires usability for poll workers. Specifically, the messages generated by a system that support its operation (e.g., set-up, opening, closing, light maintenance) must be understandable and usable at the same level as messages targeted toward the voter. Usability for poll workers was beyond the scope of our review and is not included in the discussion below.

HOW WELL ARE THE REQUIREMENTS CURRENTLY IMPLEMENTED?

The different constituencies listed in these requirements have received differential attention from manufacturers. In general, active consumer involvement has resulted in substantial consideration of the specific needs of blind voters.

Individuals with low vision, however, represent a broad spectrum of individuals to consider for usability. In general, low vision is defined as having a visual acuity worse than 20/70. Common characteristics of low vision include: dimness of vision, haziness, film over the eye, foggy vision, extreme near-sightedness or far-sightedness, distortion of vision, color distortion or blindness, visual field defects, spots before the eyes, tunnel vision, lack of peripheral vision, abnormal sensitivity to light or glare and night blindness. Many of these individuals will not define themselves as having vision impairment and will not be associated with organizations of the blind. Discussions with manufacturers suggested that they did not know if they were getting a broad array of visual capabilities among their usability participants.

Most manufacturers acknowledge they have done significantly less usability testing with the population of individuals with dexterity limitations, stating that they found it difficult to identify test subjects. This is also evident in the limited number of solutions proposed to meet the needs of these voters.

There is also no evidence that usability testing substantially includes non-English speakers with disabilities. These voters may be less familiar with technology in general and adaptations for people with disabilities in particular, and may be less familiar with the voting process.

Usability testing requirements do not specifically take into account differences related to age or differences resulting from common disability combinations such as combined hearing and vision loss, combined vision and dexterity limitations, or cognitive limitations in combination with vision or hearing loss. The requirements also do not specify that individuals with hearing loss or individuals with cognitive limitations be among those who must be included in usability testing.

Finally, there is no protocol for conducting usability testing and no benchmarks or standards. This leaves development of testing criteria and determination of results entirely up to the manufacturer.

RECOMMENDATIONS

1. Guidance should be established for manufacturers regarding usability performance expectations for people with disabilities. These could be in the form of usability protocols, benchmarks or other relevant guidance.

2. The requirement for inclusion of people with disabilities should extend to people who have cognitive or hearing limitations regardless of whether or not they use the disability accommodation features of the voting system. There should also be emphasis placed on usability testing with individuals who lack English proficiency or are non-English speakers.

3. To fully include individuals with low vision, dexterity limitations, hearing loss, cognitive limitations, individuals with limited English proficiency, individuals with multiple disabilities, and those who are non-English speakers in system testing, it will be necessary to reach out to organizations such as senior centers, disability consumer organizations, culturally diverse organizations, long term care facilities and the general community since many of these individuals do not see themselves as having a disability. Manufacturers can ask all consumers if it is easy for them to perform particular actions associated with seeing the ballot and activating the equipment.

4. Manufacturers should also consider that, as with any disability, blind people may also be seniors and have additional limitations associated with cognition, hearing, dexterity, mobility or English proficiency. These issues that may add additional

impacts to blindness should be more consistently and methodically considered when conducting usability testing of features designed to accommodate people who are blind.

CONCLUSIONS

In general, the voting systems we reviewed met accessibility requirements based on when the system was implemented. To some extent, all of the systems work for particular disability groups, and, it should be noted, most are still in use across the country. We noticed significant improvement between older systems and newer ones, suggesting that the trend is towards better accessibility and usability.

The VVSG 1.1 draft guidelines identify many of the considerations that developers must address when developing new voting systems. Within the context of the guidelines, we noted many ways that developers could improve their systems for both accessibility and usability.

However, there are gaps in the guidelines and there is a need to consider a more functional (rather than disability-specific) approach to accessibility, a need to expand usability testing requirements, and a need for future research.

DEVELOP FUNCTIONAL, RATHER THAN DISABILITY SPECIFIC, GUIDELINES

The VVSG guidelines are currently set up to focus on disability groups (e.g., voters who are blind, voters with hearing disabilities) rather than differences in function (e.g., limitations in vision, hearing, mobility). Requirements should be organized functionally rather than by disability categories, because it is easier to apply functional requirements to a broad range of people and easier to develop usability criteria if we think of the functions required to complete an action (e.g., activating the ballot; getting instructions/help; obtaining information on ballot; selecting choices; verifying ballot choices; submitting ballot) rather than the limitations of a specific set of users.

The functional approach has been taken in other sets of standards and guidelines. For example, the current version of Section 508 has functional performance criteria in addition to technical standards and the proposed “Refresh” of Section 508 only uses functional criteria (e.g., must be at least one mode that can be used (a) without vision, (b) with limited vision, (c) without perception of color, (d) without hearing, (e) with limited hearing, (f) without speech, (g) with limited manipulation, (h) with limited reach and strength, and (i) minimize photosensitive seizure triggers). The Web Consortium Accessibility Guidelines (WCAG 2.0) are another example of guidelines that start with function rather than classes of disability.

It is important to note that one can still define guidelines for different populations, but we recommend starting with function and working down to how guidelines apply to populations rather than the other way around. When we start with the functional capacity, it allows developers to enlarge their vision to include people who they may not typically think about. For example, if developers think broadly about people with low vision or limited hearing, they will include a huge population of individuals who are

experiencing age-related hearing and vision loss. The key to reducing barriers is to include all people who have a range of limited function, not just a disability type.

EXPAND USABILITY TESTING REQUIREMENTS

It is our expert opinion, based on both the evidence of the systems we worked with and the VVSG requirements, that voting systems overall are not as usable for some populations as for others. Currently the guidelines require testing for those who are blind, have low vision, or limited dexterity. Usability testing requirements should be expanded to include all people who have a range of limited function (as discussed above). In addition, it is important to include individuals with common combinations of disability such as hearing and vision loss together or any functional limitation with cognitive impairment or limited English. This is particularly important to address the large numbers of individuals with age-related functional impairments.

It should also be noted that currently there is no consideration for the large population of people who have both significant vision and hearing loss (deaf-blind). Guidelines should be developed for inclusion of this population in accessible voting.

Expanded usability testing is important as part of the certification process, but needs to be guided by better research on the needs individuals with a wide range of functional impairment. Such research would improve the design knowledge that can then be tested in determining whether a system should be certified.

NEED FOR ADDITIONAL RESEARCH AND DEVELOPMENT

There should be an increased focus on development of systems that are based on readily available technologies to reduce cost, simplify operation and enhance flexibility. This does not necessarily mean voting on a laptop or on a tablet. Instead, it means using these devices as the base unit for voting systems. It cannot be expected that all voters would be able to use these technologies off the shelf, but could use them in modified configurations specific to voting.

In general, this suggests a move away from stand-alone voting machines that are expensive to maintain and difficult to train people to use. Doing so will address concern that users are not familiar with the technology and the resistance to purchase expensive technology that doesn’t get used. Much of the current interest is in using off the shelf technology (e.g., PCs, tablets). The advantage of these types of devices is that they are readily available and people with disabilities may know how to use them. In addition, they are portable, easy to take to the voter, and easy for the user to manipulate. However, the challenges are that while these devices may have accessibility features, they are generally buried in the operating system (OS).

Developers should focus on designing voting applications that bring accessibility features into the application rather than expect users to use accessibility features from

the OS because not everyone will know how to use these features (e.g., many people do not know how to use screen readers, magnification, etc.) New systems must include all characteristics of accessibility in a standalone application and not rely on features in the OS.

A second important area of research involves a greater emphasis on plain language both for voting systems and for election specific issues such as ballot measures and specific instructions.

A third area of research should involve developing systems that can accommodate a broader range of people with functional limitations. As noted above, seniors with a range of age related issues and individuals who are deaf-blind are two categories who are not well served. However, a functional approach should address the broadest range of voters possible. Moving to a system where developers think functionally will be critical.

In general, we need more research on the "lowest common denominator" about what sort of interactions are well enough known and intuitive enough to learn to act as a core set of design principles for accessible voting systems. We need developers to consider the wide range of functional abilities and disabilities that are present in the voting population and define the critical components of a voting system (e.g., hardware, user interface, presentation/language) and the critical tasks that need to be completed to complete a vote (e.g., activating the ballot; getting instructions/help; obtaining information on ballot; selecting choices; verifying ballot choices; submitting ballot). These components need to be reduced to the simplest form to allow the most people to be able to vote and then we need research that supports new development as well as ongoing testing to monitor implementation.

REFERENCES

2010 ADA Standards for Accessible Design, 707.61 Input Controls.

McGrew, G. (2012). Assistive technology for the voting process. Washington, DC: Information Technology & Voting Foundation.

National Council on Disability (2010). National Disability Policy: A Progress Report. Washington DC: Author.

PL 111-274—Plain Writing Act of 2010. 123 STAT. 2861.

Section 508 (29 U.S.C. § 794d).

Section 508 Refresh: http://www.access-board.gov/sec508/refresh/draft-rule.htm.

APPENDIX A: VOTING SYSTEMS REVIEWED

Location	Manufacturer	Name	Type	Notable Accessibility Features
NIST	Hart	eSlate (with VVPAT)	DRE	Audio ballot; high-contrast; tactile-controls; jelly-switches
NFB	Hart	eSlate	DRE	Audio ballot; high-contrast; tactile-controls; jelly-switches
NFB	Diebold/Premier	AccuVote TSX	DRE/Touchscreen	
NIST	Diebold/Premier	AccuVote TSX (prototype)	DRE/Touchscreen	
NFB	ES&S	iVotronic 6-Key (accessible)	DRE/Touchscreen	Audio ballot; high-contrast; tactile-controls
NFB	Sequoia	Edge2Plus	DRE/Touchscreen	
NFB	Avante	Vote Trakker	Full-Face DRE	Uses PC keyboard
NFB	IVS	Inspire	Vote by Phone	
NFB	ES&S	AutoMark VAT	Electronic Ballot Marker	High-contrast; jelly-switch; Sip 'n Puff; Tactile controls; audio ballot
NIST	ES&S	AutoMark VAT with AutoCast	Electronic Ballot Marker	High-contrast; jelly-switch; Sip 'n Puff; AutoCast; Tactile controls; audio ballot
NIST	MicroVote	Infinity Voting Panel (with Double-talk A/V device)	DRE	Audio ballot; head-stick
NIST	ES&S	DS200i	Optical scanner	
NIST	Unisyn	OpenElect OVO	Optical scanner	
NIST	Unisyn	OpenElect OVI	DRE/Touchscreen	Audio-ballot; jelly-switches; Sip 'n Puff
NIST	NIST	Prototype voting system	DRE/Touchscreen	
NFB	EveryoneCounts	Ballot on Demand System	Web-based	

APPENDIX B: VENDOR PRESENTATIONS

- Democracy Live: http://www.democracylive.com/
- Dominion: http://www.dominionvoting.com/
- ES&S (Election Systems and Software): http://www.essvote.com/HTML/home.html
- Everyone Counts: http://www.everyonecounts.com/
- eVOTZ: http://www.evotz.com/
- Helios: http://heliosvoting.org/
- IVS: http://www.ivsllc.com/
- Microvote: http://www.microvote.com/
- Open Voting Consortium: http://www.openvotingconsortium.org/
- Oregon Secretary of State Elections Division: http://oregonvotes.org/
- Prime III: http://www.primevotingsystem.com/
- Scantregrity: http://www.scantegrity.org/
- Scytl: http://www.scytl.com/
- Unisyn: http://www.unisynvoting.com/