

# Research in Accessible Voting Report<sup>1</sup>

Final report for subcontract of Research Alliance for Accessible Voting:  
Creating audio, graphical, and physical technology, to address voting process and product.

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**FIGURE 1 DAN GILLETTE, SHAMA HOQUE AND TED SELKER IN A PROTOTYPE REVIEW**

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## 1. Executive Summary

This report describes results of the Research in Accessible Voting (RAV) subcontract of the Research Alliance for Accessible Voting (RAAV) grant from the Election Assistance Commission. The Research in Accessible Voting (RAV) work was performed at CMU-Silicon Valley and at the Data Democracy Initiative at CITRIS at the University of California Berkeley. New techniques were developed and tested to improve physical, cognitive, and perceptual accessibility of voting.

RAV research addresses technological opportunities for improving voting for individuals with disabilities throughout the current voting process in the United States. The projects range from solutions that can be implemented with no change to equipment or process, to those that provide direction for next-generation voting systems, with a focus on audio voting, electronic voting interfaces, visual aids for paper ballots, and polling place operations. The direction of the projects was motivated by experiences with existing voting equipment and prototypes, poll watching, and interviews with election officials. All RAV software prototypes will be released into the public domain, allowing other researchers to build on the work.

### 1.1. Projects:

Below is a brief overview of RAV activities conducted as part of RAAV. A section below provides details for each project.

1. Freestanding Ballot Magnifiers: Created the Magnifying Illuminated -Support (MI-S, pronounced “my eyes”), a freestanding magnifier for improving focus on and legibility of paper ballots. These are currently being tested by election officials.

2. Write-in Techniques for Audio-Only Ballots: Developed a technique for improving the entry of write-in candidates for voting systems that do not possess an alphabetic keyboard. Prototypes were developed to explore a variety of new methods for alphabet browsing, instructing voters, and mapping of buttons/controls. The technique allows for quickly browsing the alphabet in a structured manner that improves usability in noisy environments, such as polling places [Gillette].

3. List Browsing in Audio-Only Ballots: Prototypes were developed to explore a variety of existing and new list browsing techniques for audio interfaces, such as audio-only ballots. This published work showed that lag in feedback greatly affects the efficiency of audio ballots. Additionally, we showed that gaps between list items can be condensed without a loss in usability.

4. Low Error Voting Interface (LEVI): Significant enhancements were made to improve feedback overview and redundancy in ballot design. The techniques are designed to reduce cognitive and perceptual problems with ballot overview, focus, and redundant feedback. We built prototypes for and collaborated with projects at Clemson University (PRIME III) and Maryland (online ballot marking wizard) to embed LEVI features into their systems. Additionally, a new web version of LEVI was created which allowed for the exploration of new techniques for tracking one’s selections during the voting process, and a new software architecture based on web2.0 technologies. The web services version allows for easier distribution for testing (the new system runs in a browser) and for including LEVI in others’ research. The system is available for use at



**FIGURE 2 AD HOC LIGHTING IN A DARK POLLING PLACE**

<http://researchinaccessiblevoting.bitbucket.org/levi2>. A video demonstration of the voter interface is available at <https://www.dropbox.com/s/pux38k5nojv0891/LEVIhtml5.mp4>.

5. **Polling Place Support Tool:** A web-based interactive polling place design and management system was developed. The system supports the design, analysis, and preparation of polling place layouts prior to an election. It can provide procedural support for opening and closing the polls. It can document problems during Election Day for election auditing and learning. A video overview of the system is available at [https://www.dropbox.com/s/s310kfmexkiq2wv/pollingplacesimulator\\_x264.mp4](https://www.dropbox.com/s/s310kfmexkiq2wv/pollingplacesimulator_x264.mp4), online demonstration of the system is available at <http://pollingplace.nettempo.com:3000/#/> .

6. **Scrim:** Scrim is a web-based, semi-transparent overlay with focus apertures that can be added to voter registration and education websites to improve flow and focus, especially for individuals with reading and memory disabilities, without webpage redesign. This Scrim Chrome extension is available for download at <http://researchinaccessiblevoting.bitbucket.org/Scrim%20v1.2.zip> A video demonstration of Scrim guiding a user through a webpage is available at <https://www.dropbox.com/s/efyrm8g3eswtp6m/Scrim%20demo.mov> .

7. **Website Accessibility Analysis Tool:** The website Analysis Tool provides visualization and data to understand accessibility problems. It presents webpage color and brightness issues graphically. It presents font usage, font size and alternative accessible text statistics graphically. The Chrome extension is available for download at <http://researchinaccessiblevoting.bitbucket.org/Scrim%20v1.2.zip> . A video demonstration of web Disability Analysis is available at <https://www.dropbox.com/s/6emue4akikn1o11/website%20Analyzer%20Quick%20Demo.m4v> .

8. **DRE Instruction Set Analysis:** Instruction set scripts were collected from a variety of Direct Record Electronic voting machines (DREs) audio-only ballots and analyzed for consistency, coherence, and efficiency.

9. **Accessible Voting Technology Course:** A course was taught at CMU-SV that yielded 5 projects, viewable at <http://cmu96772.wordpress.com/>. Projects included our first web accessibility tool, Polling Place Support Tool, a Wii controller-driven voting scenario, and a polling place locator.

10. **Annotated Bibliography:** As part of getting started, the project created an annotated bibliography. It can be accessed at <https://www.dropbox.com/s/xd10idzbs9451ij/RAV%20Bibliography%20final.pdf?dl=0> .

## 1.2. Report structure

The final report is organized as follows. It includes an Executive Summary in section 1, sections describing each project, a Conclusion, a list of References, and Appendices. Sections 2 and 3 describe simple approaches to help with perceptual interfaces in voting. Section 2 describes MI-S, illuminators, and magnifiers for paper ballot support; this is followed by Section 3 showing audio voting improvements for write-ins, the most difficult audio-voting task. The report moves on from there to more universally accessible opportunities. Section 4 shows progress on Low Error Voting Interface which could greatly reduce problems in making voting selections for people with cognitive disabilities, slight visual disabilities, for sample ballots, and for overseas voters. In accordance with universal design, LEVI style ballots can also reduce lost votes for all voters [Goler]. Section 5 shows tools RAV built to help web masters notice and reduce webpage visual and alternate screen-reader text problems, improve online access to voter information and registration, and make sample ballot marking more successful. Section 6 presents a new tool that could solve polling place training, operations and auditing problems. It describes two iterations of web-based polling place support suites. As polling place problems often disenfranchise individuals with disabilities, the tools help training, polling place planning, setup, problem resolution, and closing. Section 7 is even more exploratory. It describes a Nintendo Wiimote gesture-based voting platform that might address a variety of physical disabilities. Section 8 describes a number of smaller RAV projects that motivated the major projects or have valuable implications for policy creation regarding voting with disabilities. The report concludes with section 9, asserting that technological solutions must continually be explored as part of policy creation. We promote continued technology research funding support. Funded research is necessary to create and understand policy options and opportunities to increase available solutions for allowing individuals with disabilities to successfully vote privately and independently.

Much of the code can be found at <http://researchinaccessiblevoting.bitbucket.org>. The voting course work should be viewable at <https://cmu96772.wordpress.com/> . Links to videos and other materials are included throughout this document.

### 1.3. Staffing

Below is a list of the principle contributors to the work and writing in this report:

- Ted Selker: Director
- Dan Gillette: Research Scientist
- Shama Hoque: Research Assistant, software developer: all projects
- Ashwin Arun: Research Assistant, LEVI, magnifier, audio ballots and instruction sets
- Aja Hartman: Research Assistant, MI-S magnifier
- Linda Avendano: Student in CMU-SV Accessible Elections class: Polling Place Support Tool
- Kate Liu: Student in CMU-SV Accessible Elections class: Wiimote voting
- Minh Pham: Student in CMU-SV Accessible Elections class: Wiimote voting
- Mike Vroomen: Student in CMU-SV Accessible Elections class: webpage assessment
- Rahul Rajan: Research Assistant, software developer: Audio Voting
- Cliff Chen: Research Assistant, software developer: Audio Voting
- Joey Hsiao: Research Assistant: Audio Voting
- NetTempo Inc.: Technical assistance and project management: web-based LEVI system
- Pepper Consulting: Technical assistance: web-based LEVI system

### 1.4. Acknowledgements

This work is a direct result of the insight and foresight of the EAC to focus on technology for voting with disabilities. The work would not have been possible without Jim Dickson's constant caring and thoughtful encouragement. We also enjoyed the collaborations with and appreciate all the support from our larger Research Alliance for Accessible Voting project. We appreciate the input and support from EAC, NIST, and the Caltech/MIT Voting Technology project. We appreciate the collaboration with and potent feedback from Linda Lamone and her team in Maryland. The feedback from Conny McCormack and Wendy Noren has been a constant source of deep wisdom. We appreciate access to the deep experience and thoughts of Dean Logan, Tim MacNamara, and others in the Los Angeles Registrar's office. We appreciate our access to the fine people at Disabilities Advocates, the election officials in San Francisco, and the many vendors and election officials who took time to interact about our work. Finally, we are appreciative of Mary Knoll for her administrative support, and Ellen Shay, Bob Parks, and Kathy Silke Prewitt for their patient support in writing and editing this paper.

## 2. Optical Magnifiers and Illuminators for Paper Voting Materials

### 2.1 Magnifier – Summary

RAV recognizes that paper ballots have increasingly been the preferred way of conducting elections. The illuminated magnifier is intended to ameliorate issues voters with moderate visual impairment may encounter when using paper ballots. Most people over 50 need magnification to read a ballot. Tremor is the most common movement disorder [Smaga] and negatively impacts any hand-held magnifier. Reading disabilities also affect approximately 45 million Americans [Shaywitz]. Finally, approximately 5 million Americans live with Alzheimer’s memory loss [Alz], for which physically-organizing actions can be of assistance. A device that structures movement through a ballot, illuminates it, and magnifies it could improve voting for these populations. RAV worked through dozens of designs to create the Magnifying Illuminated Support (MI-S), a freestanding magnifier for improving legibility of paper ballots and improving voter focus while using it [Figure 11]. This is currently being tested by election officials.

### 2.2 Magnifier – Introduction



**FIGURE 3 ASHWIN ARUN REVIEWING A BALLOT IN THE LAB**

A growing portion of US voters experience difficulty reading paper ballots due to evolving trends in ballot design and national demographic trends among voters. Voters may be challenged by the size of ballot text and reading conditions inside the polling booth, such as a lack of lighting and glare.

The potential for reading difficulties and errors on ballots is heightened in the United States. [Figure 2], for example, shows a polling place with ad hoc poor quality lighting added after the polls opened. Counties have increased the use of paper-based systems over electronic systems in recent years. Font sizes on paper ballots are limited, as ballots often have more than ten races and sometimes as many as 100. These factors can especially create difficulties for voters with diagnosed and undiagnosed reading problems.

The potential for residual votes, a race that was over-voted or under-voted and will not be counted in the election [Alvarez], is also greatly impacted by trends in ballot layout. Interviews with election officials suggest that those who manage elections are reluctant to carry a single race over two printed pages because, in the past, many voters have not noticed the second page of candidates, which generated uncountable “residual” votes. As a result, there is a trend to condense the typeface used on ballots to fit each race on one page. Also, the number of local propositions has increased across the US, with an additional onus placed on the voter to read multiple paragraphs of text, sometimes in a small typeface which adds to difficulties for tens of millions of people with moderate visual impairment. There is evidence that when a race on a ballot with only a few selections is just above or just below a race with many, voters skip the race with few selections. In Sarasota, Florida, for example, a poorly designed ballot for a highly politicized race had over 13% falloff for a <sup>2</sup>famous and highly contested second race on the ballot. A nearby jurisdiction with the same ballot problem had 21% falloff on a less known race [Sarasota].

The number of older Americans with often improperly diagnosed reading difficulties is increasing. Most people over 50 need glasses. The national prevalence of age-related macular degeneration alone is calculated to be around 1.5 million people, but the number is likely to double by 2020 (Eye Diseases Prevalence Research Group, National Institutes of Health). Overall, the population of the US is aging, with the number of Americans over 65 currently at 14 percent of the population, and is projected by the Census Bureau to increase to 20 percent by 2030.

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<sup>2</sup> The race was to replace Katherine Harris’s congressional seat (who is known for stopping the Florida recount in 2000)



As people age, many acquire strategies to overcome moderately impaired vision in their daily lives without formal intervention. They may not seek intervention such as glasses or renewed prescriptions, and so they may not be prepared to read material with typefaces as small as those found on ballots. Voters with severe vision impairment or blindness are likely to possess their own assistive technology or employ other assistive strategies that would allow them to vote, either on paper or with an accessible voting machine. However, a much larger set of individuals with moderate vision impairment or reading disabilities often have difficulty getting through a ballot as well. For instance, one's reading prescription may be adequate for pleasure or computer reading, but may not be strong enough to read small ballot print, due to size and/or poor lighting conditions. In many cases, the needs of individuals with moderate vision impairment have been too diverse for generalized solutions to be provided in the polling place. While magnifiers are available at most polling places, poll workers often forget to offer them to voters, and they tend to be inadequate for the task.

### *2.2.1 Magnifiers - problems with traditionally available approaches:*

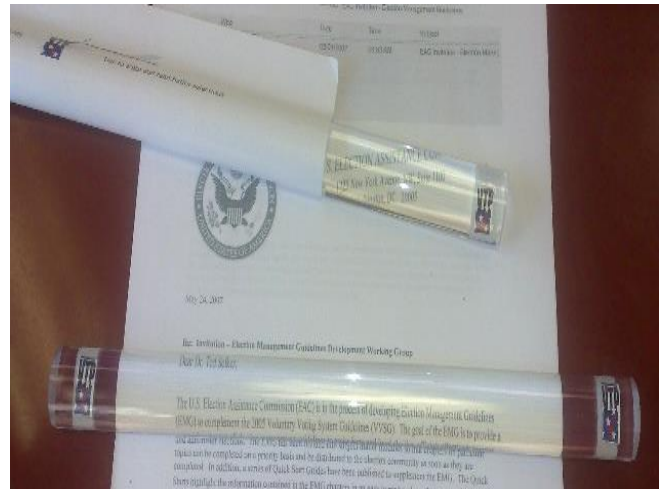
- Inexpensive hand-held magnifiers are the common solution. Unfortunately, these must be held with one hand, stopping a voter from holding a sample ballot worksheet or stabilizing their ballot as they mark it.
- Any problem with physical coordination such as tremor compromises the use of hand-held magnifiers.
- Frequently picking up and putting down the magnifier is likely to cause additional disruptions to attention. Common magnifiers are typically manufactured with a width narrower than a typical ballot page, causing users to move the device from left to right in steps, often momentarily losing their place in the text.
- Polling stations rarely have a place for holding another piece of paper. Therefore, referring to notes or a sample ballot must be accomplished using only one hand. This can compromise the error-reducing practice of referring to a sample ballot.
- Many jurisdictions use hand-held Fresnel lenses, which are able to magnify a large area with limited distortion. Unfortunately, their flat design makes them prone to being overlooked by voters and scratched as they are laying around. When they bend, Fresnel lenses also distort the image they are magnifying. Additionally, the focal length is often too short to allow writing underneath, forcing one to give up magnification during the marking step of the voting process, which has the likelihood of significantly increasing errors.
- Magnifiers may also be difficult to hold steady for many users, especially for populations with tremors. Indeed, dexterity and grip strength have been found to correlate directly with reading rate when using a handheld magnifier [Dickinson].
- Voters also show an inclination to bend over a ballot to look through a traditional magnifier, creating an unnatural posture [Figure 3].
- Lighting also greatly affects the use of the sheet magnifiers commonly found in polling places. The optical properties of the lens attenuate light under the device, further degrading reading conditions for a population that many require optimal lighting. Meanwhile, strong lighting above the device may create glare on the magnifier's reflective top surface, obscuring the field of view beneath.
- A 2002 voting study found that test subjects who used a ruler to keep their place as they read down the page made fewer errors in [Goler].
- A final problem to highlight is that a lack of training in magnifier use has been shown to negatively impact reading rate [Cheong 2005). As users train with magnifiers, they become accustomed to the magnification level inside the viewing field. Cheong showed that short-term practice with a magnifier in an optometrist's office was effective in increasing reading rate in patients, to a degree that matched their rate with large-print media. Trained users also tend to move the page under the magnifier for greater success, instead of moving the magnifier across the page [Dickinson]. However, voters with moderate low-vision and/or reading difficulties are typically not identified before entering the polling booth and many do not identify themselves. Short-term practice could be then used to improve the value of any magnifying prosthetic that a voter uses.

To address these issues, RAV iterated through a series of magnifier designs specifically intended for use in the polling place, arriving at the improved MI-S voting magnifier. Additionally, feedback from prospective users with moderate vision impairment (the target demographic) and from election officials was incorporated into our design process.

### 2.3 MI-S Magnifier - Design and Testing

The MI-S magnifier hardware design has been created in an effort to remedy the reading, writing, and ergonomic challenges which have been exacerbated by the typical magnifier designs for voting while also remaining affordable. The device went through seven prototype stages.

Ted Selker first began exploring polling place magnifiers in the Caltech/MIT Voting Technology Project. The first design was a barrel magnifier with fuzzy feet to slide easily on a page [Figure 4]. To help focus voters on an individual race, the magnifier only magnified in one dimension. The idea was to simplify keeping checkboxes and association aligned. The barrel magnifier was fashioned from a half-round 1 inch diameter rod. Enough of these were made to give one to each Secretary of State, to publicize problems and possible solutions for voting this way. Because it physically covered what it magnified, it needed to be moved away to allow marking the ballot.



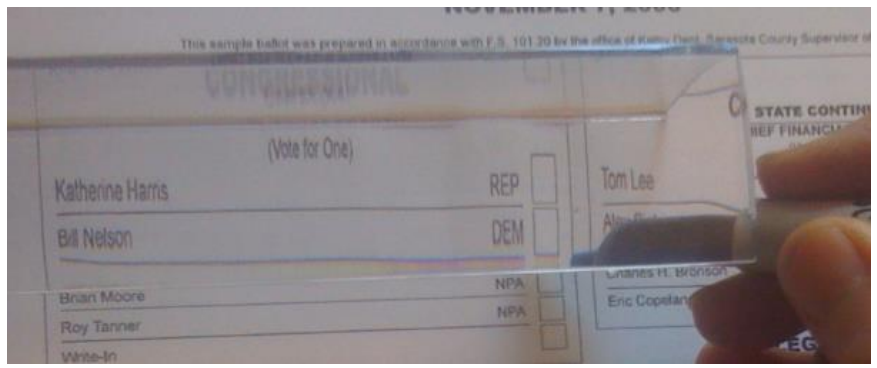
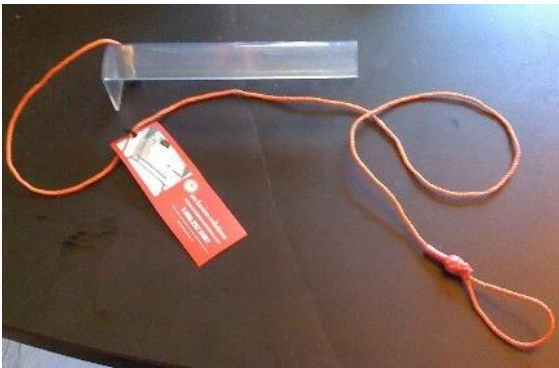
**FIGURE 4 HALF-ROUND BARREL MAGNIFIER**

The image shows a half-round rod that lies directly on the ballot magnifying through the rod in the vertical dimension.

Several goals became part of the device design focus. We needed a device that would:

- Stay where positioned for one-handed use to make it appropriate for individuals with dexterity and upper-limb disabilities
- Frame single sections of the ballot at a time to address cognitive disabilities
- Not in the way during ballot marking
- Available in the voting booth to allow people to decide to use it when needed

These considerations resulted in the voting magnifier currently available from Inclusion Solutions. This magnifier is an injection molded, free-standing barrel magnifier that stays stable magnifying what is being marked as selections are made. It has a magnification greater than 2, and stands on its own [Figure 5]. This version has an etched, horizontal line slightly above its center spot, to guide the eye across a line of text. A tether is included for attachment to the leg of the polling booth; an instructional diagram is also attached to the tether. The transparent nature of the magnifier allows maximum



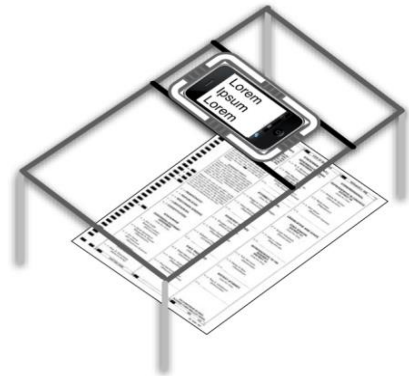
**FIGURE 5 SELKER'S MOLDED BARREL MAGNIFIER USED IN MANY JURISDICTIONS**

THE LEFT IMAGE SHOWS A 2 INCH HIGH 1 3/8 X 8 INCH CLEAR PLASTIC MAGNIFIER. IT SHOWS A CORD TO ATTACH THE MAGNIFIER TO A POLLING BOOTH. THE CORD HAS A CARD WITH A CARTOON SHOWING HOW TO INSTALL, HOLD, AND USE THE MAGNIFIER TO MARK SELECTIONS UNDERNEATH IT. THE RIGHT IMAGE SHOWS A PERSON MARKING A VOTING SELECTION UNDER THE MAGNIFIER.

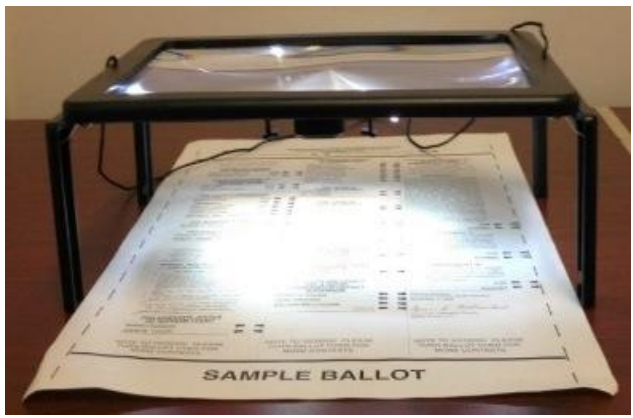
illumination of the ballot from ambient light. As one votes, the magnifier can be moved down the page using just one hand, helping voters keep track of where they are in the voting process without having to let go of the marking pen. By being freestanding and smaller than the entire ballot, the magnifier also assists in holding a user's place in the ballot, which is especially important for individuals with reading disabilities, attentional difficulties, and short-term memory problems.

Thousands of these magnifiers were acquired by municipalities [Inclusion]. While a clear improvement over handheld sheet magnifiers, there was a clear need for further refinement. Concerns developed around the need to stand directly over the magnifier to view the ballot correctly. The viewing area was problematic when reading the multi-line text of initiatives; there was no built-in illumination and the quality of the lenses was variable. Indeed, the biggest problem came from the fact that molding the lens and base together caused difficulty in creating quality optics. The MI-S RAV magnifier work below is motivated by several difficulties marking under this low device: its field of view, reflection caused by lighting from above, its illumination distortion, and magnification problems.

As a result, we began to explore how to resolve these issues with new designs. An electronic magnifier could illuminate the ballot and its display, digitally enhance the image, and otherwise help a voter keep track of their progress. An adjustable stand to hold a voter's mobile phone for use as a digital magnifier was developed [Figure 6]. Unfortunately, many mobile phones have an offset lens so that the users' hands and pens would not appear where expected. It would also be expensive to deploy such a device. Additionally, many jurisdictions are outlawing the use of mobile phones in



**FIGURE 6 ARTIST'S SKETCH SHOWING A PHONE AS PART OF A MAGNIFYING SYSTEM**



**FIGURE 7 COMMERCIALLY AVAILABLE STANDOFF MAGNIFIER: UNSTABLE, HIGH GLARE, UNEVEN ILLUMINATION.**

The image shows a commercial fold-up standing magnifier with a flat Fresnel lens on top that straddles a ballot. It has illuminators that create uneven artifacts on the ballot. Its batteries don't last long enough to use for voting.

the polling place. We reverted to improving the molded magnifier.

The use of a barrel lens in the first molded version reduced the viewable area and didn't actually appear to significantly improve voters' ability to keep track of their position, so it was abandoned for the use of flat Fresnel lenses. By moving to a Fresnel lens, we were able to achieve magnification both horizontally and vertically, allowing for more text to be read before moving the magnifier. We built standoff magnifiers and adapted commercially available illuminating magnifiers. The vertical magnifiers [Figure 7] would not easily allow viewing from in front of the polling booth. Inexpensive solutions did not evenly illuminate and created glare. We designed cantilevered stands with illumination made from plastic bins and acrylic. They had many advantages. To best understand where to position the lens, we built a platform for experimenting with the height and size of the lens [Figure 9].



**FIGURE 8 STUDY OF FRESNEL WITH CANTILEVERED LEGS**

We experimented with device's lens choice, width, viewing angle, and height off the page. Tilting the lens ~12 degrees is a trade-off between ergonomics and optics (if a lens of the desired size of four inches deep is tilted past 15 degrees, the text at the top and bottom of the lens would be distorted by the change in focal length). To allow for greater ease while marking the ballot, the position of the lens was raised. This also helped to achieve a slightly higher-level magnification. We eliminated the left leg of the original design to better accommodate ambidextrous marking. The field of view was vertically increased to aid interactions around longer races and paragraphs describing initiatives. Finally, we found that adding a built-in light could greatly improve readability and reduce glare reflected off the surface of the lens [Figure 10, 11]. We tried making angled larger standoff magnifiers in various ways. Achievements for the device include allowing hands-free use with a viewing angle pitched slightly toward the user. The new devices have slightly higher magnification. They sit higher off the page, allowing the user to write beneath it with either hand. The lens itself would allow higher light transmission and exhibit low reflectivity from above to prevent glare. A downward-facing electric light originating below the magnifier raises the illumination levels. Additional goals were to allow easy setup, left hand/right hand independence, portability, a wider base to allow stacking, and the ability to fit into existing polling-booth geometry. For instance, the device would have a tether to keep it attached to the booth and word-free instructions on the tether to instruct poll workers and voters. Unfortunately, the acrylic voting stand blocked writing easily underneath and was delicate. For flexibility of experimentation, we found a wire frame holding a magnifier to be an excellent choice [Figure 10, 11]. This wire frame design turned out easy to manufacture as well and is the



**FIGURE 9 A SPECIAL POLLING STATION STAND FOR TESTING MAGNIFYING ANGLE AND POSITION**

current MI-S testing platform with 100 devices available for election officials and others to try.

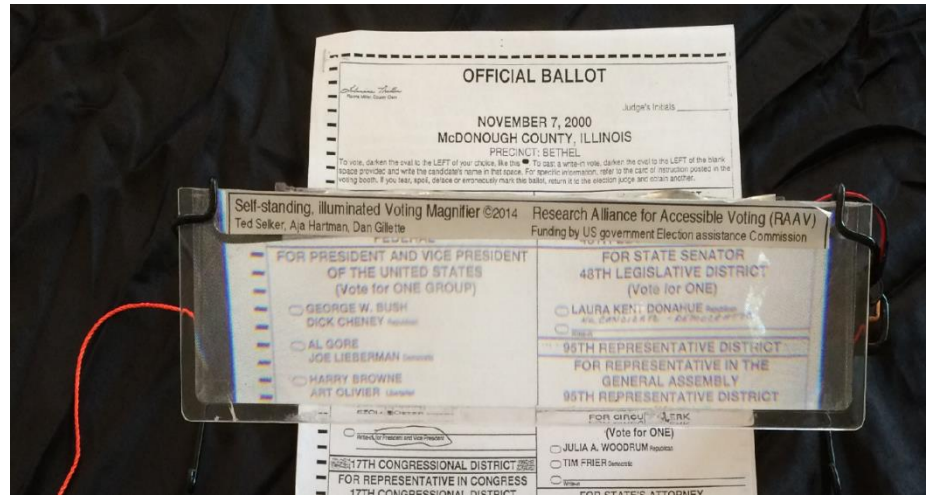
The purpose of this design is to improve voting for individuals who cannot read small text, individuals with tremors who have difficulty holding a magnifier steady, individuals with attentional difficulties, individuals with reading disabilities who may benefit from a mechanism that helps structure progression through the ballot, and anyone else who may need help keeping track of multiple tasks during a challenging, unpracticed activity.

#### 2.4 Magnifier – Experience

As tested, MI-S measures 12 inches wide at its base, with a lens of 11 inches wide. The depth of the lens is 4.75 inches, and the device stands 4.5 inches high to accommodate the use of writing instruments underneath. In addition, the device uses an LED light powered by a 9-volt battery, which was suggested by some election officials over the use of plug-in illumination [Figure 10,11].

During development, several researchers and students experimented to determine an appropriate magnification level. The optical magnification level of the test device was deemed most effective at a 2.5 times normal, similar to typical handheld magnifiers. Too much magnification appeared to be disorienting to users; the 2.5 magnification rendered a text size comparable to a large-print book, but preserved the context of the other items around the highlighted text. With the lower magnification and a total lens depth of 4.75 inches, the device's field of view displayed several lines of text at a time, providing good contextualization and ease of reading multi-line text.

When magnifiers with a narrow depth were tested, the need to move the device up and down to read a paragraph tended to cause a loss of one's place in the reading. The final design reflects weighing the benefit of a shallower field of view for structuring the reading activity, versus a wider one for giving a contextual overview. The horizontal aspect of the design itself helps users structure the activity, while the larger aperture aids in orienting users to a larger context. Several prototypes were built to establish an effective tilt angle, placing the lens in a custom jig made by cutting slits in cardboard. The tilt was around 15%, which allowed a user of average height to stand normally in front of a poll booth. The final



**FIGURE 10 EARLY SMALL VERSION OF WIRE FRAME MI-S SELF-STANDING BATTERY POWERED MAGNIFIER**

The image shows an 11 inch wide magnifier on a wire stand magnifying the ballot. A battery is visible on the right that powers this magnifier for 12 hours.



**FIGURE 11 FULL SIZED PLUG IN VERSION OF MI-S**

The image shows a 4.75 inch by 11 inch magnifier held 4.5 inches over a ballot area with a wire stand. It also shows an illuminator power supply with a card on its cord. The language-free, cartoon on the card shows how to install and use the magnifier

version is a Fresnel magnifier with a stand constructed of stiff bent wire that holds the magnifier 4 or more inches off the paper.

## 2.5 Magnifier - Discussion

To many, a magnifier appears to be a simple intervention for voters with reading difficulties. However, in addition to magnification, our experiences showed that illumination, height from ballot, and size of the reading area matter. The area shown through MI-S mimics the scrolling of electronic interfaces, in terms of their potential to direct and serialize voter attention. A freestanding magnifier (in contrast to a manually-held device which must maintain focal length) does several things. It places relevant content in front of the voter's eyes, in a stable state, at a comfortable viewing angle. It can ameliorate problems for voters with hand tremors. It can ameliorate low vision. It can also help a voter keep their place while referring to notes or election materials; voters can look away from the ballot then look back to find their place, aiding attention. In addition, the view through the magnifier's lens extends across the page, highlighting a limited number of text lines, in the same way that an effective electronic voting machine interface can focus on race while maintaining the larger context. This work suggests that such a magnifier may also help voters with normal vision who have cognitive impairments such as attention deficit, offering a tool for completing a paper ballot that they can certainly read, but may have trouble following in its compressed format.

Even without a significant improvement in reading speed, magnifiers with interventions to direct reading (such as a guide line) elicit a positive response from users with reading difficulties [Cheong 2005]. Cheong has also shown that such devices can give users confidence, which in itself may reduce errors. Conditions at many polling places are such that voters feel pressure to finish marking a ballot and relinquish the polling booth to others in line; poll watching experience finds voters with and without reading difficulties frequently making hasty selections, because they simply want to finish a cumbersome and protracted process.

Many voters may put themselves outside the category of users needing interventions. Challenges to adoption of such a magnifier include hesitancy from users without severe vision or cognitive impairments or from users who may have undiagnosed impairments. The value of a tether to maintain a magnifier in the polling booth is particularly important to allow voters to casually use the prosthetic, without having to leave the booth and ask for help.

The optimal deployment of magnifiers would be to have them tethered to each polling station before the polls open. Alternatively, some polling sites provide reading glasses to voters. This could be an extremely positive remediation, however, such an accommodation does not structure the ballot-marking activity and could pose a health hazard as glasses are shared between voters. Additionally, election workers have found that glasses create a management problem in the polling site because of the need to loan and accept returns of the appliances.

The decision to make a battery-powered, as well as a plug-in illumination version, came as a result of the wishes of election officials.

Finally, we designed MI-S to give some of the ballot-structuring advantages that DREs offer. 2004 data showed that no state depending on paper ballots had less than 0.9 % residual errors (of a voter not successfully making a selection for the race at the top of the ballot) while all four states that used DREs had 0.4% or less [Stewart]. We believe the DRE advantage came from many user interface advantages: focusing on a race, structuring the activity, and feedback. Our goal was to take Low Error Voting Interface features and make them available for paper, in an attempt to reduce the difference in residual votes in paper ballots.

### 3. Audio-Only Voting Interfaces for Improving Write-In Candidate Text Entry

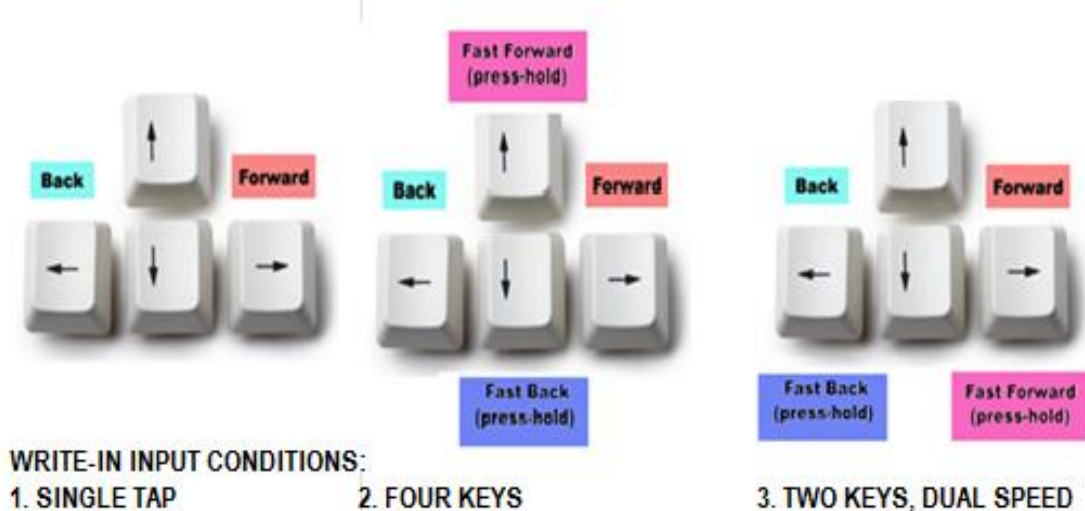
#### 3.1 Write-in – Summary

Few blind individuals are proficient in Braille. Audio voting has become an important way to allow voters who cannot read well (including individuals with reading disabilities) to vote independently and privately. Unfortunately, the process can take many times longer than that for a graphical ballot, due to the way text is presented, confusing feedback, and poor navigational schemes. To resolve these issues, RAV has explored how to improve audio-only voting.

Ted Selker’s previous work in the Caltech/MIT Voting technology project is a backdrop for the RAV audio ballot prototype. A first student project by Reesa Phillips explored using 3D to improve orientation and reduce time for voting. While promising, the ability to use 3D to orient a voter is brittle. Such an advanced use of audio will require much more development. Another effort of ours used “abbrevivicons” - speaking a reduced version of often spoken control words. Mathew Hockenberry worked with Ted to show that the approach can significantly reduce speaking time in audio ballots [Hockenberry]. Vendors have been encouraged to consider using the abbrevivicon idea in their audio interface systems. The RAV audio work focused on input for selecting items in a long list, like an alphabet, for the purpose of writing a word that must be done for write-in candidates. RAV created and published work suggesting that audio lag, and requiring the user to listen to entire selections before moving on (as in many of today’s voting systems), are both impediments to usability. The project’s prototype audio-only write-in process was improved with simplified button controls. The work also indicates increased usability with structured audio presentation, when background noise or distractions are present.

#### 3.2 Write-in - Introduction

Many constraints impact an accessible voting experience for voters who cannot read a graphical ballot. While a tactile Braille interface is often suggested by those new to the problem, in the United States only 10 percent of blind individuals are proficient at using Braille [Jernigan], and not all voters are familiar with typical text-input and assistive technologies, such as standard keyboard layouts or screen readers [Granata]. As a result, the 2005 Voluntary Voting System Guidelines



**FIGURE 12 KEY INPUT CONDITIONS FOR AUDIO WRITE-IN EXPERIMENTS**

(VVSG) specifies that the inclusion of audio-based voting be provided [United States Voluntary], while allowing for voting privately, independently, and verifiably (the ability to confirm one’s choices before casting a ballot). Because of the lack of voter training opportunities, user interfaces should be usable without prior training. Direct Record Electronic voting machines (DREs) have therefore been developed with a simplified button-input array that controls an audio-only user interface. With DREs, screens are typically blank during audio voting to preserve the privacy of the vote. Such audio DREs might seem simple for some voting tasks. However, the multiple processes of inputting the name of a write-in

candidate, selecting characters, checking accuracy, making edits, and submitting one's choice can be especially frustrating and time consuming. Many voters who use the audio write-in feature need extra time and commonly fail to enter a name at all. In practice, such interfaces have presented voters with their most difficult task of the election experience [Herrnson], contributing to a higher ratio of unrecorded votes [Niemi]. For this reason, RAV has focused on how to improve the write-in experience by exploring how to better use controls, provide instruction, and improve input-editing strategies.

Speech recognition and auto-completion of text might seem appropriate for writing in a candidate's name. Unfortunately, these technologies would spoil privacy and could even be inappropriately coercive for voting. Using speech recognition for direct text entry in the polling place, where others can listen in, would jeopardize one's right to vote privately. In the case of auto-completion, there are also many issues that cannot be resolved. To begin with, auto-completion requires that words be previously known by the system, but many states do not require write-in candidates to pre-register [Helm]. Additionally, in the context of voting, auto-completion can potentially introduce coercion, by priming the voter think of one candidate over another through the ordering of suggestions. For these reasons, we focused on creating new text entry methods for audio-based write-in that does not rely on alphabetic keyboards, speech recognition, or auto-completion of text.

This section covers the development and testing of three novel audio interfaces that enable navigation and selection of characters through simple techniques that allow users to linearly access an alphabet for the purpose of typing a specific name, discussing the strengths and weaknesses of each in relation to existing methods.

### 3.3 Write-in - Discussion

Voting machines can be designed according to several sets of guidelines, most notably the Federal 2005 VVSG, which designates that every polling place should have at least one accessible voting station. Such devices are intended to allow people to use a range of adaptive input devices such as an Audio-Tactile Interface (ATI), intended to provide voters with earphones and a set of buttons, or a sip and puff device for non-manual use (with graphical or audio interfaces). The VVSG includes guidelines for volume, frequency, and speed of audio between 75 and 200 percent of normal rate of speech. The VVSG does not specifically address how write-in candidates should be entered by voters who do not use graphical interfaces. We followed guidelines on how operational instructions are to be given by audio at initial activation, and repeated as desired during the voting session. Our prototypes also fell within the VVSG guidelines for audio speed, after iterative testing and refinement.

Several researchers and students helped to determine reasonable rates for presenting audio. Participants found that audio with the standard speech rate equivalent of 200 words per minute (WPM) seemed slow, while an equivalent rate of 700 WPM and higher was incomprehensible. Though audio at a rate of 500 to 600 WPM could be understood, users found it too fast for maintaining comfortable and accurate navigational control. As a result, audio generated at 400 WPM was considered appropriate (in line with the VVSG's upper limit of 200 percent above normal). This also fits with the findings of Asakawa, et al, on general comprehension of listeners of sped-up synthesized speech, which saw an upper limit for comprehension at around 300 to 500 WPM (278) [Asakawa]. The prototype platform strayed from the VVSG in regard to providing multiple modes for navigation keys, depending on whether the key is tapped quickly or held down.

The VVSG suggests that press-hold commands (for instance, repeating the entry of a letter if a key is held down) be avoided as an attempt to limit unintended letter entry, but we introduced such a capability into two of our three prototypes to see if the command's utility might outweigh the concerns posed in the VVSG. The potential to positively impact future criteria is a goal of our work, adding to the motivation to reevaluate existing guidelines.

The goals in developing the three prototypes were to test how to best orient the user during the text-entry task, shorten the amount of time required to enter a candidate's name, and improve accuracy. The prototypes were created in a Google Chrome browser extension, built with HTML and JavaScript. The extension utilized Chrome's text-to-speech capabilities to generate audio feedback, and also HTML5 to manipulate audio files. These were generated using text-to-speech



features in the MAC OS X command line interface. While the system works with Windows machines as well, the testing was conducted on a 2012 MacBook Pro.

A version of the prototype was created for each condition listed below:

- Condition 1, Single Tap with Two Navigation Keys: Participants moved through the alphabet one letter at a time by tapping the left or right arrow keys to navigate; selections were made by pressing 'Enter'.
- Condition 2, Four Navigation Keys: Participants used the Up and Down arrow keys to navigate through the alphabet at 400 words per minute (WPM), pausing to distinguish marker letters (A, G, M, T, Z), and the Left and Right arrow keys, to navigate one letter at a time.
- Condition 3, Two Navigation Keys Utilizing Two Speeds: In contrast to the single tap, with these two-key conditions participants used only the Left and Right arrow keys for navigation. By holding down the keys, users moved through the alphabet at 400 WPM, pausing to distinguish marker letters (A, G, M, T, Z), and then navigating one letter at a time with single taps.

The rationale behind the development of marker letters was to provide a fast way to navigate closer to an intended target letter by browsing through groupings, to select the target letter with only a few key presses. The initial exploration divided the alphabet evenly, but informal testing indicated that most people do not have an adequately stable model for where lesser-used letters fall in the alphabet. Most people, however, could easily establish a letter's location in the alphabet by recalling its proximity to commonly used anchor letters. Through trial and error we found A, G, M, T, and Z to work best as markers (or waypoints) to segment the alphabet.

Experimental instructions for write-in experiments:

"To write in a candidate's name, follow these instructions:

1. [Condition 1] "Single-tap the Left or Right arrow key to move through each letter. Press Enter to select a letter."
2. [Condition 2] "Press and hold the Up or Down arrow key to find the general area for the letter you are looking for. Single tap the left or right arrow key to narrow in on the letter. Press Enter to select the letter"
3. [Condition 3] "Press and hold the Left or Right arrow key to find the general area for the letter you are looking for. Single-tap the Left or Right arrow key to narrow in on the letter. Press Enter to select the letter."
4. "To move through the alphabet quickly, like this [play audio sample], press and hold the Left or Right arrow key. Try it [allow user to try]."
5. "To move one letter at a time, like this, press the Left or Right arrow key. Try it [allow user to try]."
6. "To select a letter, press Enter. Find and select the letter S [allow user to try]."
7. "To review what you have already typed, press the Up arrow key [allow user to try]."
8. "To remove the last letter typed, press Delete [allow user to try]."

"To listen to the instructions again, press the Down arrow key. To begin, press an arrow key."

To test our prototypes, thirty computer science graduate students participated. All possessed average vision, none were regular users of text-to-speech technology, and only one was a native English speaker. For each condition, participants were asked to enter two different names. The order of conditions was randomized. The time taken to input eight letters using each approach was compared. Each test condition had a sample size of ten participants.

The data shows a statistically significant improvement between Condition 2 and Condition 3 with a 25 percent reduction in task time when using a two-key interface over a four-key interface (with a t-test p value of  $7.1E-06$ ). In contrast, there is no statistically significant performance difference between condition 1 and 2 (t-test p value of approximately 0.88). A critical finding was that all conditions improved audio-enabled write-in speeds over existing and prototype DRE systems with a similar functionality. The majority of our testers completed audio write-in entry in less than one minute in every

trial. DRE voting equipment with audio write-in capability tends to utilize a condition similar to Condition 1, yet in the field, this method is very difficult. In field tests and observations of various deployed and emerging voting devices, selecting eight letters for a name can rarely be done in one minute. As a gauge, we looked at efforts using machines going through or carrying VVSG certification. For instance, on a Sequoia AVC Edge machine manufactured by Dominion and tested in January 2014, a user entered only four letters in 56 seconds with great effort. In addition, when the tester entered a letter erroneously on the AVC Edge, he was unable to correct it.

There are a number of reasons for slower write-in speeds on current equipment. Many DRE voting machines in current service present a lag in response—a detectable or sometimes uncomfortably long period of time between when the user presses a button and when the device responds. DRE machines with older hardware and software may suffer delays because software has not been optimized or hardware is underpowered to keep up with the voice interface. (The prototype did not present noticeable lag.) As well as lag, some systems do not register button input while audio is playing, meaning the voter cannot skip past or truncate (cut short) any information, which can impede alphabet browsing. Another factor may be key design.

DRE machines may not match the effectiveness of the prototypes using a computer keyboard because of the actual design of the DREs' specialized buttons, which are typically large and made from plastic, soft rubber, or silicone, and behave quite differently from the type of computer controls most people encounter in their daily lives. Although standard computer keyboard keys are pressed with 182 to 193 grams of pressure anywhere on their surface [Rempel], many accessible ATI buttons on voting systems vary in actuation pressure across the key, requiring pressures that are multiple times the minimum pressure needed near the hinge. Recently, our researcher team had access to a newer DRE that responded with no perceivable lag, but used the standard Accessible Technology Interface (ATI) button design. While not available for our study, in a limited hands-on test the new machine yielded vote times closer to those experienced in our test conditions, but still not as fast. It is likely that differences in key feel contributed to this difference.

Faster overall entry speeds in the experimental conditions may have also resulted from the ways the conditions attempted to orient users on how to go forward and backward, and to navigate the interface itself. This data shows that using fewer keys increased performance in both of the experimental conditions. The four-key interface was more difficult for participants to learn, remember, and use efficiently. Surprisingly, the data did not show a significant improvement for the novel press-hold feature of Condition 2 and Condition 3, over the simple tapping of Condition 1. Simply tapping through each letter one at a time enabled users to enter letters faster than they could with Condition 2 and at similar speeds as Condition 3. In interviews, however, the majority of participants reported a preference for the sped-up letter browsing of Condition 3. In spite of not being native English speakers, participants also reported that utilizing A, G, M, T, and Z marker letters to chunk the alphabet into four sections improved their sense of location in the alphabet. Although these preferences did not significantly increase text-entry speeds, participant feedback speaks to an increased comfort level with having an overview of the alphabet and a greater context for navigating it. These marker letters, however, did affect use under stress as described below.

The testing also revealed the importance of suggesting an efficient strategy to voters, rather than simply listing features in the instruction set. Without any instruction on strategy (when we described what each feature was, but not the purpose), only some participants developed efficient methods for text entry while others struggled, either sticking to using single tap or sped-up letter browsing, or frequently changing strategy. Testers who developed an efficient strategy did so by taking a moment to experiment with the controls before commencing to spell the name, but such experimentation is not easily available while voting, given the pressure of time and the fear of making an error that would affect a live ballot. When we changed the instructions to clarify various strategies (for instance, initiating a press-to-hold on an arrow key to quickly move to a letter region, or tapping the arrow keys to browse one letter one at a time), almost all used an efficient strategy from the start. The testers' response prompts the question of whether polling guidelines should encourage a period of practice, sample vote completion, or simple drills before commencing to enter write-in candidate names. Unfortunately, voters are currently unlikely to have consistent training before voting.

While not part of our formal prototype testing, an important benefit of using sped-up reading of the alphabet with marker letters became apparent when using the prototypes in noisy surroundings, such as found in typical voting sites. Many

users stated that when the volume of the prototype could not fully compete with ambient noise, it was still easy to hear the pattern of the marker letters as the alphabet sped by. This pattern made it possible to easily get within range of the target letter, and the cognitive model it developed provided secondary context to discern partially heard letters when zeroing-in on the target one letter at a time. This suggests that while there were not significant improvements in speed between Condition 1 and Condition 3, in the noisy environment of the polling place Condition 3 should present a valuable benefit in real world voting.

### 3.4 Audio – Conclusions

This work demonstrates techniques for write-in design that could be introduced in future voting machines and highlights underlying questions related to the ongoing design strategies of electronic voting equipment. The previous discussion concerning ATI button design and our experience with these specialized buttons cautions us that the presence of such unusual, specialized input hardware (presumably to show extra care and attention to voters with disabilities) may actually introduce difficulties for many users. Experiments indicate that a typical consumer-grade keyboard is much easier to operate than available adaptive input devices and would speed input. As well, the arrow configurations on such keyboards (sometimes a cross style or inverted T with Up-and-Down arrows sandwiched between Left and Right arrows as in Figure 12) are typical to most people’s communication use in daily life. While early VVSG may have been made when fewer people used computers, it has become difficult to live in society today without using a keyboard for communication and other activity. While the goal may be a variety of input methods to suit the user’s tastes (common QWERTY keyboard, Braille keyboard, or audio-tactile interface) in line with the findings of [Oliveira] in “Blind People and Mobile Touch-based Text-Entry: Acknowledging the Need for Different Flavors,” a functional interface that follows the most successful conditions in our testing would form an appropriate path for simplified entry of write-in candidates. Eliminating keyboard-to-audio lag, allowing key press to interrupt audio at any time, and varying audio speed each improved audio-based character input. In addition, structuring the alphabet with fixed marker letters did not slow input, and indeed, should make performance more reliable in the context of the perceptual and cognitive challenges of real-world voting input. The results of this work should also be useful for entry of passwords or proper names in any computer interface not relying on speech recognition or keyboard input.

## 4. Low-Error Voting Interface Development

**FAMILY COURT JUDGE**  
You may vote for one (1) candidate in this race.

<input checked="" type="checkbox"/> James H. DILLON(R) Republican	<input type="checkbox"/> James H. DILLON(D) Democrat
--	---

PREVIOUS RACE      NEXT RACE

**FIGURE 13 EARLY LEVI SHOWING A SELECTED CANDIDATE**

**U.S. SENATOR**  
You may vote for one (1) candidate in this race.

<input type="checkbox"/> Rick LAZIO(R) Republican	<input type="checkbox"/> Hillary RODHAM CLINTON(D) Democrat
<input type="checkbox"/> Jeffrey E. GRAHAM(I) Independence	<input type="checkbox"/> Rick LAZIO(C) Conservative
<input type="checkbox"/> Mark J. DURAU(G) Green	<input type="checkbox"/> Jacob J. PERRASSO(S) Socialist Workers
<input type="checkbox"/> Hillary RODHAM CLINTON(W) Working Families	<input type="checkbox"/> John CLIFTON(L) Libertarian

PREVIOUS RACE      NEXT RACE

**FIGURE 14 UNVOTED AND PARTIALLY-VOTED RACES**

PRESIDENT OF THE U.S. Vote by One	U.S. SENATOR Vote by One
George W. BUSH	Rick LAZIO <input type="radio"/>
Al GOODE	Hillary RODHAM CLINTON <input type="radio"/>
JOHN MAGELIN <input checked="" type="checkbox"/>	JEFFREY E. GRAHAM <input type="radio"/>
George W. BUSH	Rick LAZIO <input type="radio"/>
FILIPPA WADLER	MARK J. DURAU <input type="radio"/>
JAMES E. HARRIS	JACOB J. PERRASSO <input type="radio"/>
Al GOODE	Hillary RODHAM CLINTON <input type="radio"/>
HARRY BROMME	JOHN CLIFTON <input type="radio"/>
FRANK S. CASHAN	
	SUPREME COURT JUSTICE Vote by One
	FREDERICK J. MARSHALL <input type="radio"/>
	DONNA M. SMITH <input type="radio"/>
	Ralph A. DIEMELLO II <input type="radio"/>
	JOSEPH S. FORMA <input type="radio"/>
	E. JEANNETTE OGDEN <input type="radio"/>
	PAUL V. CRAPS <input type="radio"/>
	SHEILA A. DITULLIO <input type="radio"/>
	JOSEPH S. FORMA <input type="radio"/>

Page 1 of 2      Next

Touch A Name To Make Changes

PRESIDENT OF THE U.S. James E. HARRIS
U.S. SENATOR Jacob J. PERRASSO
SUPREME COURT JUSTICE DONNA M. SMITH NO Selection Made NO Selection Made NO Selection Made
U.S. REPRESENTATIVE NO Selection Made
STATE SENATOR NO Selection Made
ASSEMBLY MEMBER NO Selection Made
FAMILY COURT JUDGE NO Selection Made
DISTRICT ATTORNEY NO Selection Made

Back      Next

**FIGURE 15 LEVI SIMULATOR PRESENTING TYPICAL VENDOR BALLOT AND REVIEW PANES**

#### 4.1 LEVI - Introduction

The Low Error Voting Interface started as an effort to reevaluate electronic voting ballots in 2001. Graphical ballot design has not typically used state-of-the-art user experience and graphic design techniques. Ballot designs usually use a simple, narrow, dark line between areas on a screen. They often forego using shading, color, or texture for distinguishing a selectable item or space to separate them. They often do not vary layout spacing for different kinds of things, or in reaction to selections. Modern cognitive science and user interface research show much better alternatives. Shaded outlines are more noticeable. Border lines that mimic three dimensions with contour and shadows recruit precognitive perceptual capabilities [Ennes]. Using such cognitive science-inspired techniques should greatly improve speed and accuracy of distinctions. Texture and color can also make differences more apparent. Organizing races so that they aren't visually lost on the ballot is important. In Sarasota County in 2006, for example, 13% of voters didn't see the second race on the ballot due to a graphic design glitch [Sarasota, Selker LEVI]. My VTP LEVI work explored changing the look of a ballot so that a voter could always see the status of all races. We added a zooming feature called fisheye views, which has been shown to help people orient and focus. We made feedback for what the voter had selected redundant and obvious. Finally, we realized huge reductions in errors when we compared these to simulations of Sequoia and ESS ballots [Goler].

LEVI is designed to ameliorate several accessibility problems, while reducing error rate for all voters. It is designed with several concepts to orient and organize voting. It gives visual feedback of voter progress at all times. Texture and color are used as secondary cues to clarify whether or not more action is possible for a contest and what type of information is being displayed. Has the person completely voted for a contest? Is there is the option to vote for more contests? Controls are mode-less between voting and review, allowing ballot review during the entire process. Neither linear nor non-linear navigation loses track of progress.

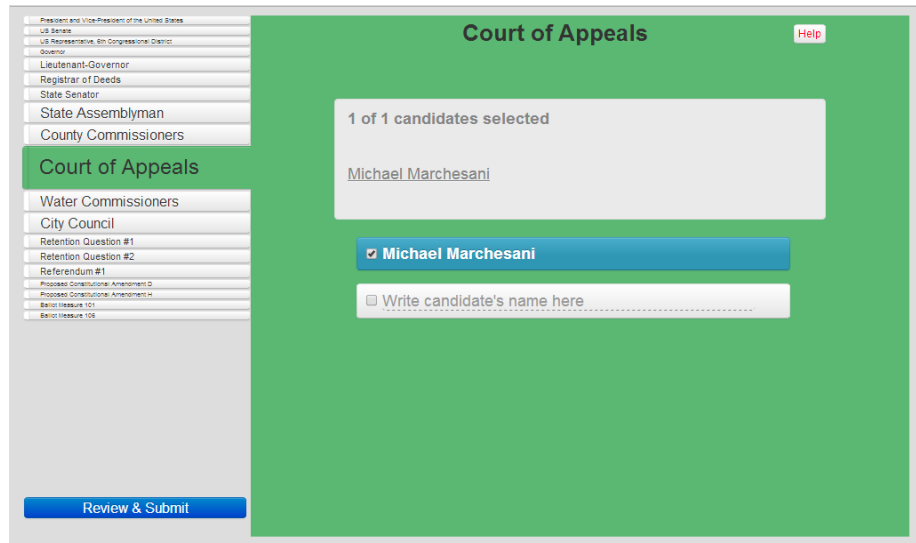


FIGURE 16 LEVI CONSTANTLY REVIEWS SELECTIONS FOR ALL RACES

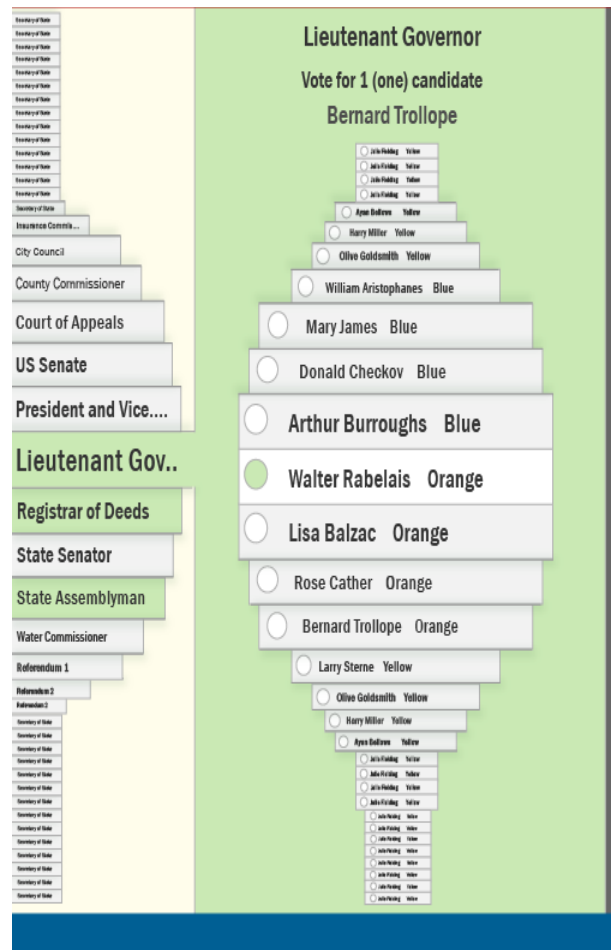
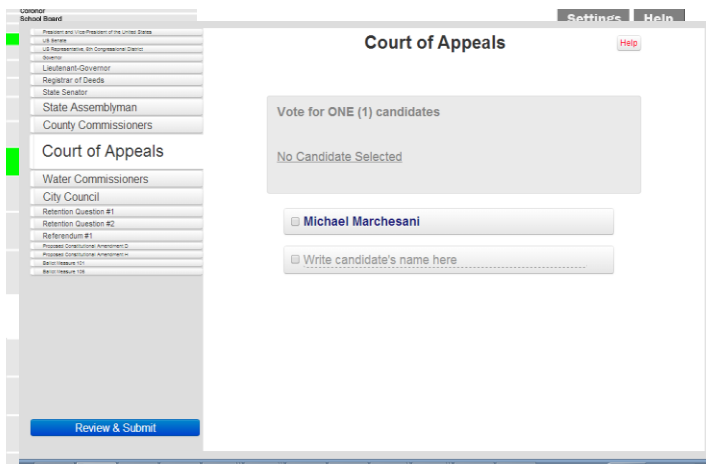


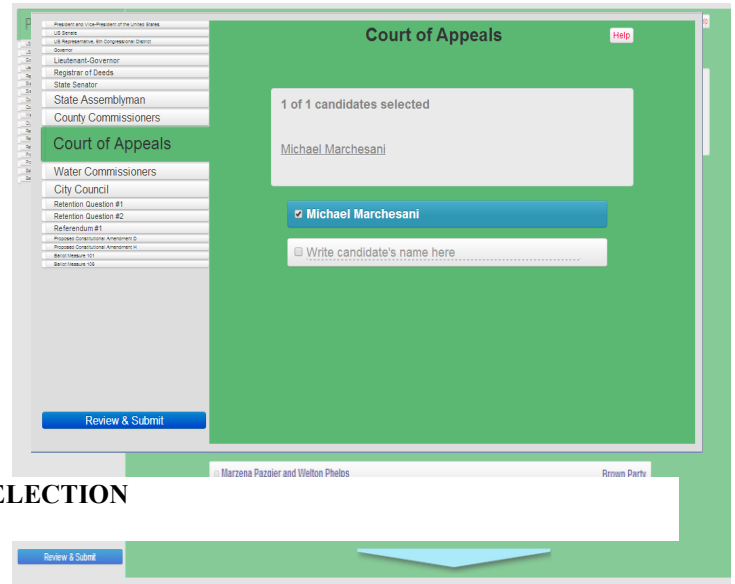
FIGURE 17 FISHEYE STUDY FOR FOCUSING WHILE VOTING

## 4.2 LEVI – RAV web Services System

The project created an HTML5 and JavaScript Low Error Voting Interface experimental platform. The system uses a



**FIGURE 20 WEB-BASED LEVI: PANHANDLE SHOWS SELECTION**



**FIGURE 19 A SELECTED RACE WITH MANY CANDIDATES**

**FIGURE 18 LEVI MOCKUP EXPLORING SCROLLING INSTEAD OF FISHEYE FOR INITIATIVES**

JSON file to define ballot goals. Live demos are available at <http://researchinaccessiblevoting.bitbucket.org/levi2-old> and <http://researchinaccessiblevoting.bitbucket.org/levi2-old/src/index.html>.

A persistent menu shows all the races and provides a method for nonlinear navigation through the ballot. It is located on the left as a sidebar. The Main Trunk features include Tabs and fisheye text. Text is full size for the selected tab; text and tabs get smaller for the other tabs as they move away from the selected tab. Color, texture, size, and border are used to increase orientation.

When a trunk tab is selected, its contents are displayed in the main content area. The background between the tab and the main content area is the same, creating a left-hand tab “panhandle” that shows the connection between the tab and its content and shows which race is active. It is magnified and opens up to the race to associate with it in the main viewing area.

Implementation of the RAV web version explored many uses of fisheye, scrolling buttons, etc. Some of these are evident in the exploration slides included. The work inspired projects by various vendors, states, and others. A working version of the system can be found at <http://researchinaccessiblevoting.bitbucket.org/levi2>.

## 5. Polling Place Support Tool

### 5.1 Polling Place Support Tool – Summary



FIGURE 21 DIFFICULT TO FIND “ACCESSIBLE” VOTING PLACE ENTRANCE DUE TO POLLING PLACE SETUP PROBLEMS

Polling places are intimidating, especially for people with disabilities. Since polling is episodic, polling physical settings are often different, making physical accessibility a recurring design challenge. Due to training and communication problems accessible voting machines are often not operational or not used during elections. Even simple lighting challenges are common in polling places. Logistical problems can multiply for people with disabilities as well.

This section describes interaction in student and final browser-based prototypes that provide assistance to election officers in several ways. The scenario supports polling place design, training, operations, problem solving, and auditing. It presents a spatial/graphical user interface for interacting with representations of voting space, furniture, and equipment layout, to assist election officers in better fulfilling polling place administrative activities before, during, and after the election.

The application, Polling Place Support Tool, is designed to improve on the current paper-based checklists an election officer uses to remember the different activities he or she has to do before, during, and after the election. The tool will be customized to include local voting materials for testing in a jurisdiction.

The RAV Polling Place Support Tool is a simulation that allows poll workers and officials to explore the possibilities for optimizing the design of an

accessible and compliant polling place.

The system’s layout capability is envisioned as a way to plan paths, ingress and egress, equipment, and furniture placement. It could train and test poll workers before the day of election.

- It could help associate check lists with particular equipment and positions in the polling place for opening and closing a polling place.
- It could allow poll workers to record situations associated with the polling place. It could let central election officials communicate about specific problems and make a lasting audit trail of problems in the polling place.



FIGURE 22 NEW ORLEANS 2006, THE POLLING PLACE SETUP DIDN’T ALLOW FOR PUBLIC NOTICE PLACARDS OR SAMPLE BALLOTS TO BE ACCESSIBLY PLACED WHERE VOTERS COULD READ THEM.

- The software then could be used to help plan everything, from the arrangement of pencils and materials, to the layout and booth arrangement and power connections in a polling place.
- It makes available a list of all pertinent factors poll workers and officials should think about while handling each aspect of the undertaking.

The goal of the application is to provide an active teaching experience for those learning about polling-place setup and the issues involved with it. The intention is for the application to provide a learning option that is better than sitting passively in a classroom or studying a leaflet. The current prototype is available at <http://researchinaccessiblevoting.bitbucket.org>.

## 5.2 Polling Place Support Tool – Introduction

Polling places are notoriously difficult for individuals with disabilities to navigate and often accessible voting devices are improperly setup. In the aftermath of the 2000 presidential election, research and statistics showed that polling place operations were responsible for losing over a million votes [Alvarez]. They rank as one of the top three aspects of the voting process that hinder and disenfranchise voters. Setting up the polling place during an election is a process that requires following strict guidelines and rules, as well as understanding how to efficiently control voter flow. Indeed, in 2013 President Obama convened a task force to look at the problems, such as long lines in polling places [Presidential].

Several mechanisms have been employed to teach people how to design and plan polling places. One is the lecture hall approach, where those learning how to operate a polling place face an instructor at the front, who discusses various parts of the undertaking. At another extreme, some poll workers might only get a color-coded leaflet that helps people to understand some parts of it.

Live presentations and leaflets might not have been the most effective approaches to teaching or motivating election workers to create seamless, functioning spaces to hold elections, especially as polling place design relates to accessibility to all voters. In recent history, significant problems have arisen during the actual operation of polling places on election days.

### 5.2.1 Polling Place - Examples

The following are examples of some of the problems that have occurred:

- In Boston in 2006, Ted watched a dark polling place with many people having trouble reading their ballots. Additional lights were installed so people could vote without flashlights in a dimly-lit auditorium polling place at 9:30 AM, 1.5 hours after the polling place opened [Figure 2].
- Polling places have literally moved from one location to another on the day of an election. In 2002, Ted Selker witnessed one being moved from the gymnasium to the library of a building at 7 AM. A change such as this, of course, alters the way in which a polling place is set up. A poll booth collapsed to the floor as we arrived. In a hastily designed polling place, people’s ballot privacy can be easily compromised by being readable by people in line to vote.
- In 2004, a voting information placard was posted on an accessible door where reading it would make the door hit the reader in the face [Figure 23].



**FIGURE 23 AN “ACCESSIBLE” DOOR THAT AUTOMATICALLY SMACKS INTO A VOTER WHEN APPROACHING THE POSTED VOTING INFORMATION**



- At a polling place in Nevada in 2004, Ted watched as all twenty voting machines at the site were plugged into one outlet. Power was lost for that outlet; when all of the batteries died 2 hours later, the polling place ceased operation. An ad hoc decision was then made: all of the machines were plugged into a different (single) outlet. That outlet, it turned out, had a microwave oven plugged into it. When a pollworker was asked, “Shouldn’t the microwave be unplugged?” another pollworker replied, “No, it’s okay.” Soon after, the polling place went down again [Figure 24] [Selker].

- To allow very local decisions, some “split ballot” precincts give different ballots to people in the same precinct. In Chicago in 2002, at a split-ballot polling place voters were given Ballot A or Ballot B. After voting on the correct ballot, they needed to scan them at the correct scanner. Poll workers in other such polling places had taken it on themselves to think this through and create a sign at the last minute with a felt marker and tape it to the scanners so that voters would know where to correctly scan their ballot. Sadly, at this polling place Ted witnessed as the ballots were randomly assigned to one of two scanning machines. Half of the ballots were, therefore, read by the wrong machine. Accidentally going to the wrong scanner would compromise a voter’s selection for a race.



**FIGURE 24 PEOPLE NOT ABLE TO VOTE ON LOCAL ELECTIONS DUE TO POLLING PLACE PROBLEM**

- In 2004, Ted visited a polling place in Boston which had four voting areas inside of a building. One of the entrances at the back of the building behind a fence was wheelchair-accessible. The door to this entrance bore a sign identifying this as a polling place, but since the door was open, the sign remained invisible [Figure 21]. Other problems, such as the absence of the check-in portion of the voting procedure and the lack of signs to identify the four voting areas, led arriving voters to line up along steep, wheelchair-inaccessible stairs



**FIGURE 25 NEW ORLEANS 2006. 50 PRECINCTS VOTED IN THIS ACCESSIBLE WAREHOUSE. POLLING PLACE WORKERS WITH POLLBOOKS USED REGISTRATION LISTS TO DIRECT PEOPLE EFFICIENTLY. THERE WERE NO LINES.**

to one of the voting areas. The line became very long and the voters didn't realize until they got inside that they could have walked into any one of the voting areas and finished voting much sooner.

- At help stations in some polling places, important information is posted below the edge of the desk, hanging well below eye level, requiring voters to lean far over, squat, or put both knees on the floor to read the material [Figure 22]. The elderly voters in the figure demonstrate how people with disabilities would miss most of this information.
- Sometimes, normal care and attention of poll workers can overcome inherent problems with polling place design and planning. Post-Katrina in New Orleans, Ted watched an election day in which dedicated helpers from the Secretary of State's office came from Baton Rouge to help people identify their voting place, reach it, and even get their cars parked. The largest polling place that day had 50,000 people assigned with no lines! This was the famous Ward 9 that had flooded during Katrina. For that reason only 5,000 – 5 times the number of people that typically vote in a polling place – not 50,000 showed up to vote. But, 5,000 people going to one polling place would be a debacle in most polling places. It was accessible and easy to navigate, because it was spacious, organized and there were people telling voters which of the 50 different precinct polling places inside that warehouse they should go to, or if they had to go to another site [Figure 25].

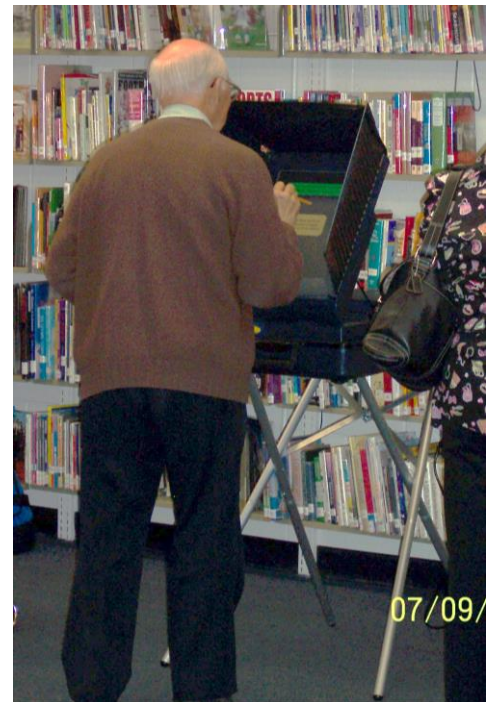
### 5.2.2 Polling Place - Training

Poll worker training varies from election to election and jurisdiction to jurisdiction. It is common to visit polling places with poll workers that were enlisted the morning of the election. It is also not uncommon for poll workers to have spent hours or days in classroom settings learning about voting. It is less common for them to role-play or simulate accessible processes. We see the training practices in polling places lean on support of more experienced poll workers, a telephone helpline, or a poll worker pamphlet on the day of election when the process is happening<sup>3</sup>.

When a problem arises in the polling place, poll workers have to make decisions in the moment without supervision, and possibly without proper analysis of the problems. Figure 26 shows a poll booth that was setup incorrectly, putting ballots in plain view of onlookers. As well, by giving the voter a pencil to poke the touch screen, the pollworker inadvertently made the touch screen very difficult to use. As we began thinking about these situations, we realized that many of the problems that polling places face could be avoided just by conceptually walking through the experience ahead of time and role playing the experience for the voter and poll worker.

### 5.2.3 Poll worker Training –Alternative

“Polling places should be organized so that all voters can be processed efficiently and voters with disabilities can navigate the voting area and participate in the electoral process without assistance”[ US VVSG]. As easy as the task might sound, it can take 178 pages to explain which guidelines and rules to follow and which activities to do before, during, and after the election to create a well-organized polling place layout.



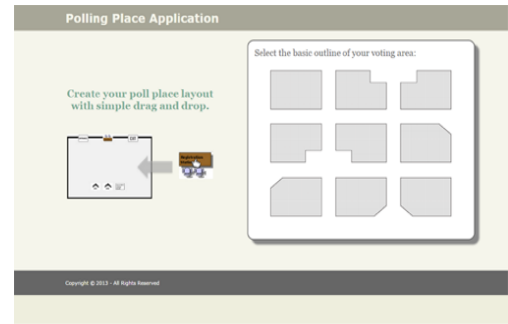
**FIGURE 26 POLLING PLACE OPERATIONS CAUSED VOTERS TO BE GIVEN WRONG INSTRUCTIONS FOR USING TOUCH SCREEN, BALLOT PRIVACY WAS ALSO COMPROMISED**

<sup>3</sup>We pollwatched in CA, IL, LA, MA, NV, NY, and talked to pollworkers from many other states.

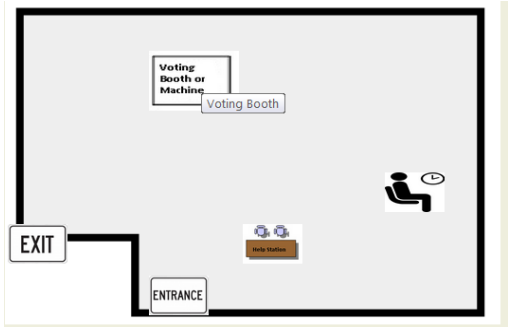
Even though technology has been used in assisting voters to make their voting experience easier, there are no tools to help the election officer to ease his or her task. There are several reasons for this. First, each jurisdiction potentially has its own guidelines and procedures to set up a polling place. Another reason is that in some states the elections office will do a “site survey” [Rick Urps, personal communication] to identify the features of the facility where the polling place will be set up, and create the layout for the polling place. The layout should not be changed once it is set by the office, so poll workers only reproduce the diagram. Third, so far people have not used tablets to assist in polling place setup. As an attempt to make some tasks easier for the elections officer, we have designed and created a prototype for a web application that will help officers and workers in setting up the polling place more quickly, and also in completing a long list of “to-dos” to comply with the laws regarding elections and regarding Americans with Disabilities Act (ADA) [US Department of Justice ADA].

The RAV Polling Place Support Tool provides an alternative to teaching with a slide-based presentation or paper-based instruction, with the goal of encouraging election officials to plan the polling location beforehand, test it, and document how to do it.

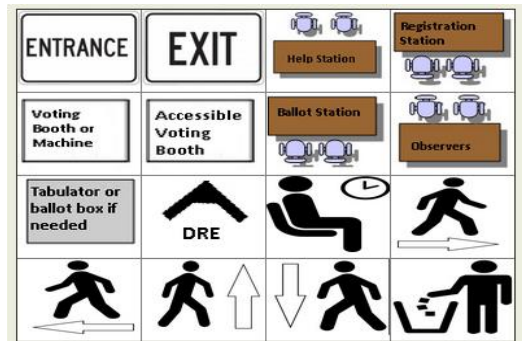
The student prototype, created as part of the CMU accessible voting technology class, included two main functions: creating a diagram on how to set up the polling place, and checking the tasks that need to be done before, during, and after the election. The final app includes documentation and communication to potentially reduce difficulties for poll workers to get help during an election. The application provides a reflection tool for the poll worker to be able to easily figure out the proper layout to make the voting area accessible with good traffic control. It should also provide enough information for the poll worker to quickly perform the tasks associated with the voting process.



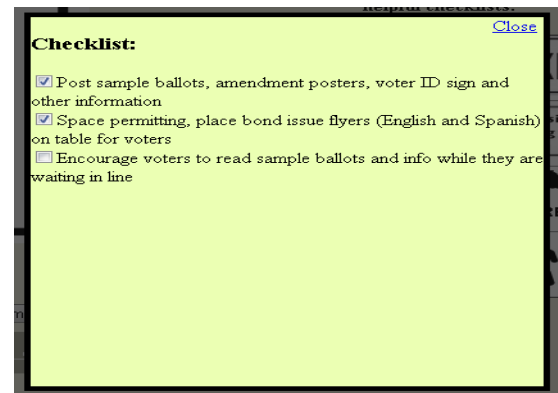
**FIGURE 27 STUDENT POLLING PLACE SUPPORT TOOL START PAGE**



**FIGURE 28 BEGINNING A LAYOUT WITH SOME ELEMENTS IN PLACE**



**FIGURE 29 TOOLBOX OF FURNITURE TO BE PLACED IN VOTING AREA**



**FIGURE 30 STUDENT SAMPLE CHECKLIST**

### 5.3 Polling Place Support Tool – Student Version

The student version was based on HTML 5, CSS3, JavaScript. The final version described in the next section was written to be scalable. It is written in JavaScript using MEAN Stack, MongoDB, Node.js and Express.js for the web server, and Angular.js for the client-side software.

The student version of the Polling Place Support Tool started using the guidelines for setting up a polling place for Fairfax County, VA [Virginia]. It provides visual representations of entrance, exit, voting booths, accessible voting booths, tabulation boxes, help station, registration station, waiting areas, and walking directions which allow the user to plan and reflect on a polling place layout.

It contained a list of “to-do” tasks that can be marked as completed within the tool. In this way the officer might be more aware of the tasks he or she needs to do, and also be certain about which tasks have already been completed. This live application can be accessed at <http://linda.nul-unu.com.s3-website-us-east-1.amazonaws.com/> .

The final version is also there; it has a backend that can support many polling places and is designed for secure login as well. It can be accessed at <http://pollingplace.nettempo.com:3000/#/> .

List of features of the Polling Place Support Tool:

- Room layout: The first page allowed the user to select a room layout that best fits with the actual dimensions of the voting area [Figure 27]. While the first version gave a user the task of choosing a room layout shape, the second version simply allows a user to block out parts of a square grid with architectural features or furniture that can't be moved.
- The toolbox contained the basic elements that a polling place should have. Examples of these elements are: exit, entrance, help station, registration station, ballot station, ballot box, observers' station, accessible voting booth, and so forth. The elements in the toolbox can be dragged and dropped into the room layout to start designing the voting area layout [Figure 29]. The second version puts such polling place tools in tabs of a toolbar that can be selected more simply [Figure 33].
- Furniture manipulation: The elements on the toolbox could be dragged and dropped into the room layout. The item could be put in different position on the layout. Once an item is added to the layout, the user can “hover” over the item to see a bigger representation of it. Features on the second version allow deeper engagement with a gear toolbox, and handles allow sizing and rotation.
- The user could click on the image to show the different activities the poll worker needs to do to set up that particular furniture. The items associated with each station could be checked too. In the second version, clicking on an item's gear icon produced a popup menu checkbox, tags, duplicate, or delete [Figure 34].
- The application could save and download a current layout as an HTML file. It also had a “reset” button to erase the current diagram and start all over again. The second version has a more sophisticated login and database load approach to working on specific polling places.
- Beside the activities that the poll worker needs to do for the polling place station, the tool provided information on the activities that he or she needs to do before the election, when opening the polls, during the Election Day, and when closing the polls. The second version includes versions of such lists in a database that can be edited.

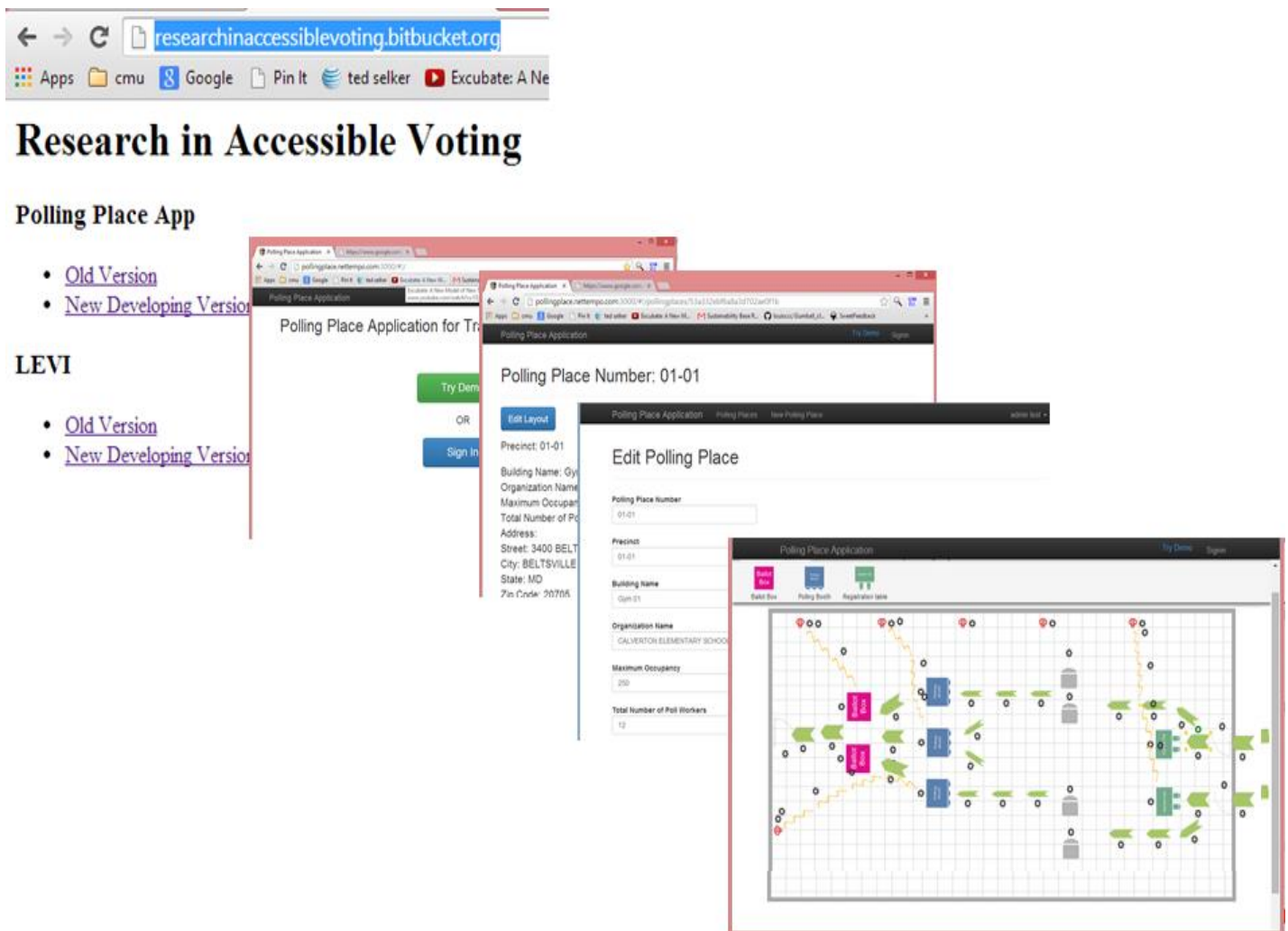
Polling place activities were organized to aid poll workers understand the sequence of the tasks they need to do.

Rick Urps, Deputy Director of Maryland State Board of Elections, provided feedback on the prototype. He wasn't sure that the Board would use the layouts previous to the election during a ‘site survey’, but he saw a lot of potential for associating checklists positions within the polling place. He said “Combining the site survey map with checklists is where

we see potential for an app such as this. In Maryland, we envision that the app is used to initially map out the polling place during the site survey, or the existing polling place map is entered into the app. On Election Day, the map and checklists are there for the chief judges to reference.”

Poll workers are often undertrained or new to the activity. We held a workshop for ten persons with little or no experience in the polling place to try using the student application. They worked in pairs using the application and reading the guidelines. They found it easy to start creating a layout but found the manipulation impoverished, so the final version below includes simple handles for sizing and rotating items. Some of them used the app first; some of them used the paper guidelines first. It took them several minutes to read the documentation to start using the application, so the final version below simplified learning and using through a simpler user interface. They wanted better information on the use of the checklist and other elements of the system; the final version below makes it easier to add modify and delete items. People wanted more status feedback; the second version below treats the poll designer and poll worker differently.

#### 5.4 Polling Place Support Tool – Final Version



**FIGURE 31 SCREEN SHOWING THE STEPS TO USING THE FINAL POLLING PLACE SUPPORT TOOL**

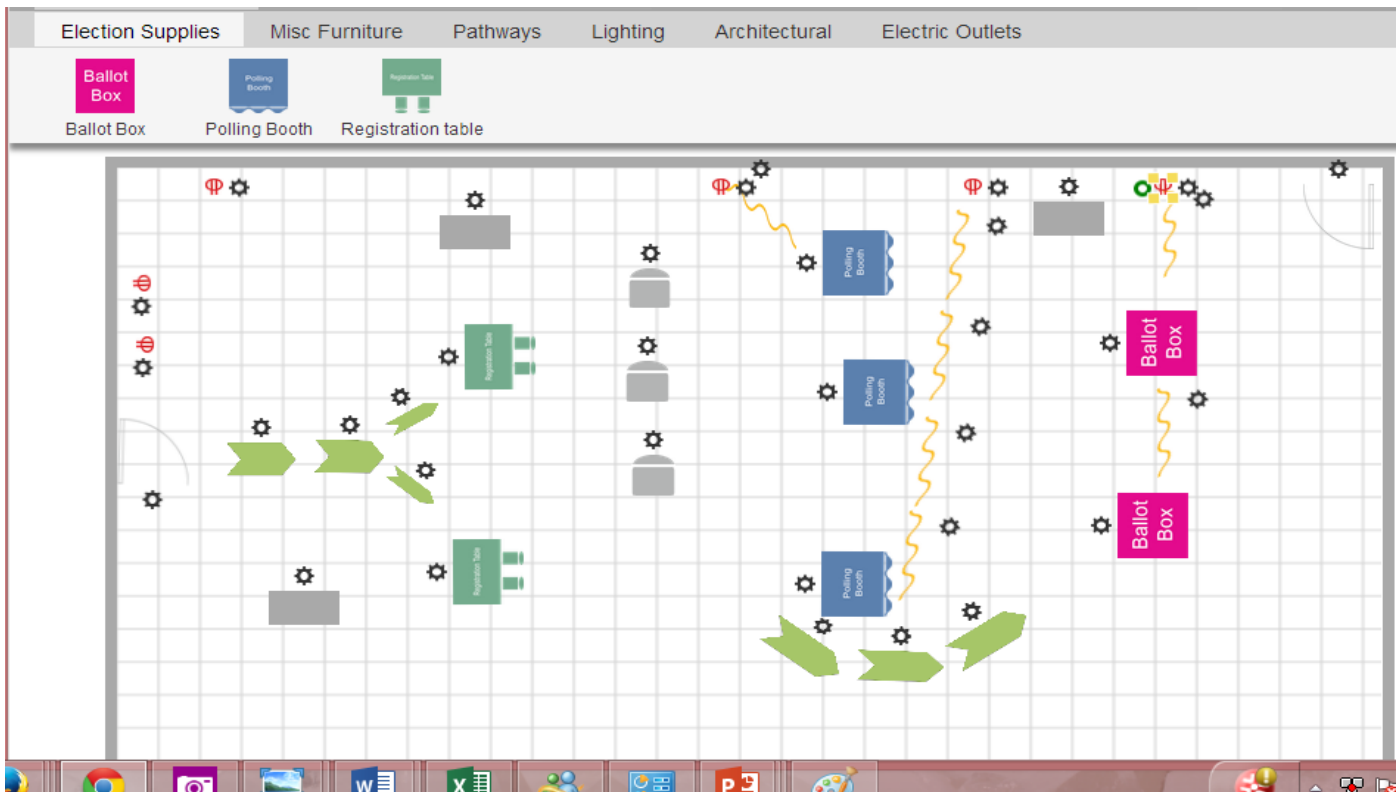
The image is a cascading set of screen grabs showing what must be selected to set up a polling place with Polling Place Support Tool. The first screen shows choosing the application. The second screen shows choosing a demo. The third screen shows choosing a polling place. The fourth screen shows a polling place with objects and paths as movable graphical objects.

## Final Version Highlights

The final Polling Place Support Tool is written in JavaScript using MEAN Stack, MongoDB, Node.js, and Express.js for the web server, and Angular.js for the client side software. A live demo can be found at <http://pollingplace.nettempo.com:3000/#/> . It solves problems found in the user exploration with the first prototype. It also adds capability to make the simulator testable for even more purposes.

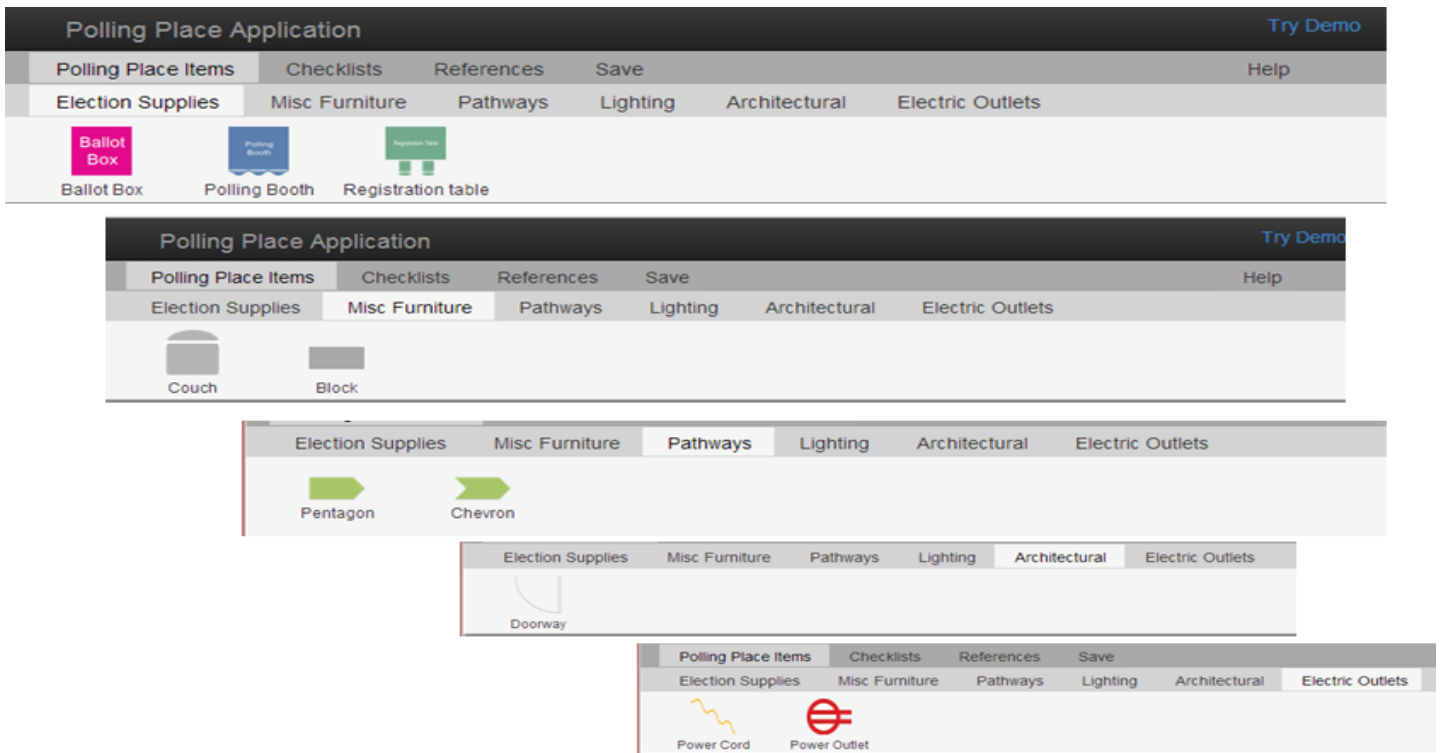
For physical accessibility, the final Polling Place Support Tool focuses on making physical obstructions and paths through the polling place a priority. Notably, it dispenses with a separate user interface for creating the room and simply allows a user to put blocks on a grid to define it. The new user experience focuses most of the screen real estate on the room itself instead of tools. It also adds important items such as electrical outlets, existing furniture, wires, illumination, and notes. Figures 31 through 34 shows screenshots showing these features.

Figure 31 shows the sequence of getting into and using the application. Going to [Researchinaccessiblevoting.bitbucket.org](http://Researchinaccessiblevoting.bitbucket.org) takes you to a screen where you can choose the new polling place application. From there, a screen allows you to try a demo or log in. If you try the system by default, you are shown polling place number 01-01, which you select to edit layout. This takes you to the architectural layout that you can experiment with.



**FIGURE 32 EXAMPLE OF PATHS, OUTLETS, CORDS, EQUIPMENT AND EXISTING FURNITURE IN FINAL POLLING PLACE SUPPORT TOOL**

The image shows a polling place layout on a computer screen. A grid on it aids knowing how much space is around things. The image has outlets, wires, walking paths, doors, registration desk, ballot box, chairs, and immovable objects in the space.

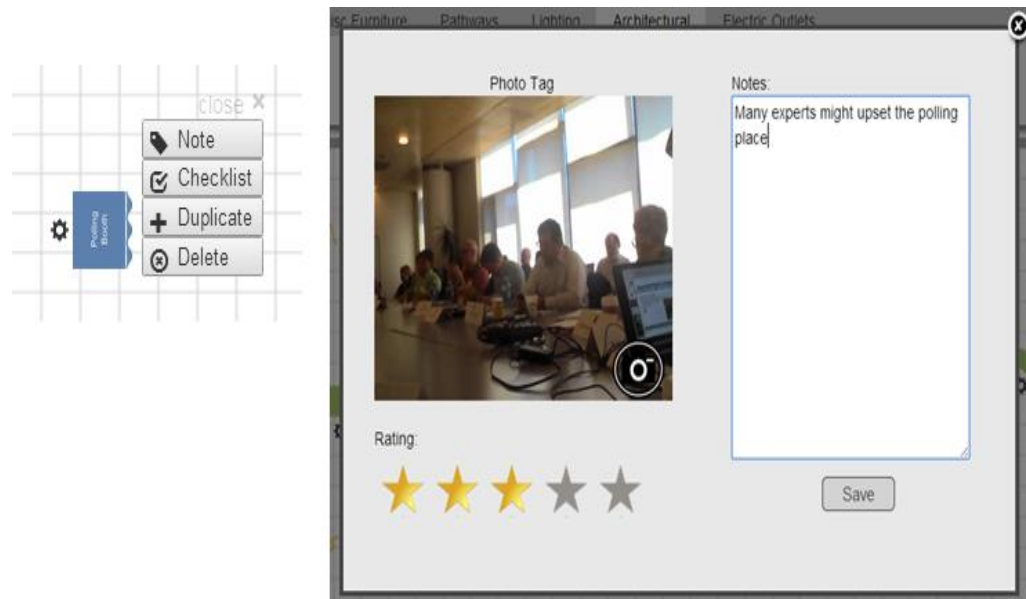


**FIGURE 33 TOOLBARS AVAILABLE FOR ADDING ELEMENTS IN THE FINAL POLLING PLACE SUPPORT TOOL**

The image shows the menu tabs for putting things in a polling place simulation. These menus shown include tab bars for Election Supplies, Furniture, Pathways, Architectural Elements, Electrical Wiring.

The application’s polling place screen presents a polling place floor plan grid and tabs for things to place in it, as in Figure 32. A grid of 1-foot by 1-foot flooring tiles indicates specifically where various elements of the polling place can be placed. The elements, such as an entrance in an architectural diagram, can be dragged from the “toolbox” on the right to spots on the grid.

Polling place designers can place a polling place element in a spot on the grid, then click on it to see relevant information. The toolkits in the new



**FIGURE 34 USING A PHOTO WITH THE FINAL POLLING PLACE SUPPORT TOOL TO MAKE A TAG RECORD FOR AN INCIDENT**

The image shows the Note selection made on a polling place object selected. The interface includes a picture taken from the laptop’s camera (several people at a conference table), a notepad pane with text about the incident being noted (“many experts might upset the polling place”), a set of stars (three selected), and a Save button at the bottom.

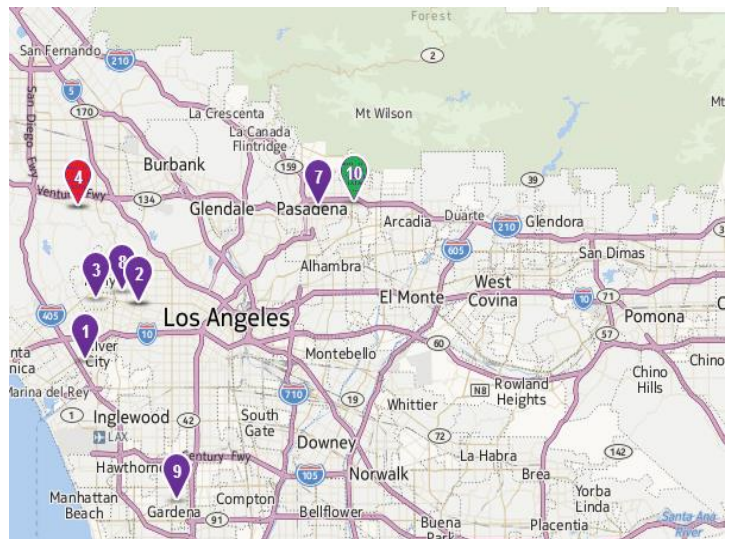
application are in tool bars shown in Figure 33. The objects include election supplies, furniture, pathways, lighting, architectural elements, and electrical outlets. Selecting one of these tabs shows a set of items that can be dragged onto the polling place grid, such as the ballot box, polling booth, and registration table icons, in the election supplies tab in Figure 33. Each placeable item has ‘handles’ to place, rotate, or stretch it. Selecting the gear icon next to the item brings up a popup menu including note, checklist, duplicate, and delete, as shown in Figure 34. Building and exploring polling places with the system is meant to have a spatial game-like experience to inspire new poll workers to learn about and succeed in setting up a polling place. The simulator becomes an interactive experience that is likely to be memorable to them.

For each of the elements on the grid, there is the option to use a device called a “tag,” which also can be clicked upon to leave a note and record the position and time shown in Figure 34. If someone is using this application on an election day, as an aid for setting up a polling place, or as an educational tool, the tag option allows this person to rate a problem, or add text and/or a photo that will appear with the element on the polling place grid. A photo of a help station in an actual polling place can be added and might be useful to whomever looks at the tag. The tag photo could show how the setup election device should look on Election Day. The photographs could also be used by an online help desk to diagnose problems remotely, such as a poorly positioned sign hanging below the desk. An employee at a town or city's election office could view various polling places prior to the election with the application and, upon noticing an ineffective aspect, attach text to the help desk to indicate the need to post important material in a more accessible spot.

### 5.5 Polling Place Support Tool - Conclusion and Future Work

Two iterations of a Polling Place Support Tool were made. The final one is created as a professional web services app that should be deployable for testing in jurisdictions.

This platform demonstrates a range of support that can make polling places more functional, reliable, and accessible. The web-based interactive polling place design and management system can be used on most any web-enabled desktop or mobile device. Poll workers access to the app, their checklist activity, and tags can play a role in auditing. The system can be used for polling place site analysis and preparation of layouts prior to an election. It can be used for procedural support for opening polls, for closing the polls, for facilitating communication about problems and solutions during Election Day. Such visual and text records of polling places created with the software can be used as a reference to analyze things that happened and to consider and improve operations for the future. The next step in exploring this approach would be to deliver it for a pilot trial in a jurisdiction.



**FIGURE 35 ARTISTS CONCEPTION OF AN ELECTION CONTROL ROOM USER EXPERIENCE TO ACCESS POLLING PLACES, ESPECIALLY WHEN THEY HAVE RED, IMPORTANT TAGGED PROBLEMS**

The image shows a map with pushpin icons identifying polling places. One is green, one is red, and the rest are purple. These pushpins can be selected to bring up a Polling Place Support Tool view to help understand the problem at a site.

Figure 35 shows a rendition of a future use. It includes a control panel that could allow an election headquarters to keep track of and communicate with polling places through this application. Without phones, the central support people could then be made aware of and address problems throughout the jurisdiction. “Pins” on a map could indicate pending requests for communication. The official could view the polling place, its checklists, and its notes to be oriented as they work with a pollworker who is grappling with a problem. As well, VTP personnel at MIT have shown interest in working with the system to add a simulation mode, allowing users to see how various changes to the polling place affect throughput and other aspects of efficiency.



## 6. Tools for Improving Existing Voter Education and Registration websites

### 6.1 Adding Translucent Overlays to webpages

#### 6.1.1 *Translucent Overlays Overview- Summary*

RAV created a method for adding translucent overlays to voter registration and voter education websites to help improve focus on one task at a time, which could be especially helpful for individuals with several kinds of cognitive and perceptual disabilities, as well as for individuals with low vision. While the gold standard is to design such websites based on the best accessibility guidelines, many counties do not have the resources to do this. The Scrim app provides a mechanism for adding accessibility features without redesigning an existing website.

Scrim is currently implemented as a Chrome browser plug-in and acts as a method for graying out parts of a webpage, drawing users' attention to areas of the page, with the overall goal of improving the browsing and data entry functions of these websites. The tool is designed to allow a "trainer" to select a sequence of "apertures" in a WYSIWYG manner on any webpage. It also includes an approach for reading the positions of the objects as an alternative authoring approach. The user sequences through these apertures, viewing the material while still able to select items anywhere on the webpage. The apertures help serialize a user's path, guiding the user through reading and procedures one step at a time.

#### 6.1.2 *Overlays – Introduction*

Leading up to creating the Help America Vote Act (HAVA), registration problems were identified as the number one obstacle for citizens, accounting for over 2 million lost votes in 2000. Registering to vote online is now the preferred mechanism for voters, state governments, and the federal government as a way of facilitating registration while obtaining a driver's license. Since Arizona first put its voter registration online in 2002, followed by Washington State in 2008, online voter registration has expanded rapidly with the number of states online at 19 in 2014, providing access to 47 percent of all eligible voters. According to a 2014 Pew study, 11 of the 13 states surveyed reported greater voter satisfaction, with 65 percent of registered voters in support of online systems. Factors that influenced satisfaction included the voters' ability to instantly confirm registration through the Internet and to update personal information at any time. Online at-home registration removes barriers to participation for those with limited mobility. States have moved online because it reduces fraud and saves money, among other benefits. By using an online system, Arizona was able to reduce the cost of registration from 83 cents to 3 cents per voter. The Presidential Commission on Election Administration called for further broadening online registration to the remaining states in the January 2014 report and recommendations. By making the registration process available from any computer in a person's home, school, or library, the new approach expands beyond even the improved voting access of the Motor Voter Act, which makes registration open to anyone by simply checking a box as they renew a driver's License.

Online registration is arguably most important for people with physical, perceptual, and cognitive barriers to registering on paper at an election office. Concerns of security are simpler for registration than some online transactions as they are typically checked against several records, and in many cases require demonstration of response to mail to be validated. A drawback to the rapid deployment of online registration sites and other government sites, however, is lack of accessible user interfaces and difficulties with demonstrating their accessibility. Such sites have not been validated for ease of use, lack long-term user feedback regarding interface problems, and likely are deficient in the benefits of formal critiques from those familiar with designing online interfaces for accessibility. Any complicated online interface can disorient and disorganize a user. Government or voter registration sites are especially challenging in that they are fraught with the stress of creating important credentials and are used only once. Problematic issues include the number of steps involved in the process, and the difficulty of accessing pages and fields where the voter needs to enter essential information. Some voters with cognitive impairments may face additional challenges when trying to navigate the steps in the specified sequence required by the form.

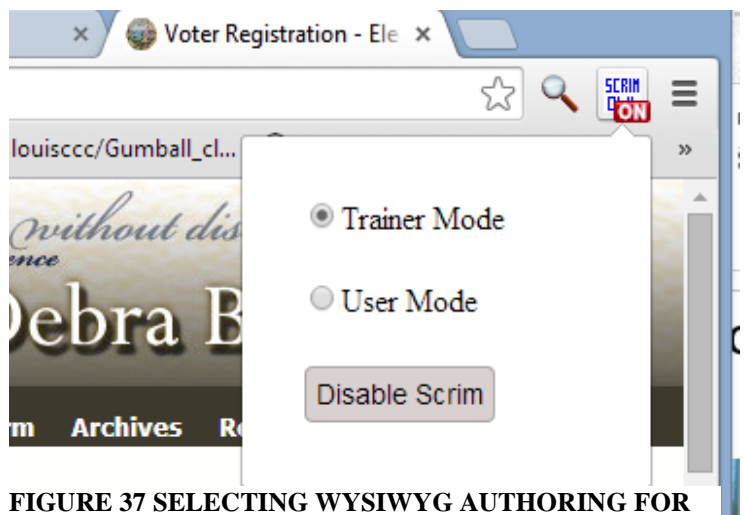
A prominent factor in the high number of unregistered voters in the US (more than 51 million citizens or 24 percent of the eligible population) remains the persistent impediments to registering, especially for those with cognitive disabilities or low vision. The portion of such users among the unregistered group is likely significant, given the number of such users in the general US adult population. US citizens with mild short-term memory loss (excluding dementia) number between 3 to 4 percent and the prevalence of US adults with attention deficit hyperactivity disorder is over 4 percent. Adults with dyslexia number at least 10 percent, and those with low vision (excluding blind adults) make up 2 percent. The increase in the incidence of diabetes in the population can be associated with vision problems as well. Considering learning disabilities in general, one could extrapolate the adult population with learning disabilities from that of American public school students, which is approximately 5 percent of the total public school enrollment. Another important user group coming to registration sites includes the undetermined number of citizens who have difficulty focusing, but who have not recognized it, disclosed it, or sought professional help to diagnose it, in addition to those who have a modest degree of distraction that cannot be categorized as a cognitive disability or impairment.

RAV has created Scrim, a Chrome browser plug-in that acts as a method for drawing voters' attention to specific areas on the page by hiding most of the page with a semitransparent "scrim" and showing the area to focus on via a transparent section called an "aperture". The extension is available for download at <http://researchinaccessiblevoting.bitbucket.org/Scrim%20v1.2.zip>. Research shows that people can select through scrim without cost to time, but can find material in apertures as fast as if it is the only material on the screen [Klein]. The software does not impede the legibility of the screened parts of the pages, as it focuses attention on the apertures. It allows election administrators, with minimal training, to create a pattern ahead of time for where aperture openings in the scrim appear and their sequence for the user to fill out information on the page. The result draws the user's attention to a specific area on the computer screen. As they select or fill in material in the aperture, a new aperture guides them to the next required action. They are drawn by their successes through the steps of filling out a registration form or other web interface.



**FIGURE 36 SCRIM INTERFACE HIGHLIGHTING CITIZENSHIP DECLARATION SELECTION**

The image shows the California Secretary of State webpage covered with a blue scrim tint everywhere except for a box surrounding the selection "I am a US citizen, I will be over 18 by the next election". Below this white box are two round buttons: one for down, one for up. These buttons take the viewer to the next crucial thing to select in the web experience. All selectable objects on the webpage continue to be selectable through the blue tint scrim.



**FIGURE 37 SELECTING WYSIWYG AUTHORIZING FOR OVERLAY TOOL**

The image shows that selecting the Scrim Chrome extension icon opens a window. The window shows a button for selecting, one for selecting user mode, and a large "disable scrim button".

### 6.1.3 Translucent Overlays Related Work

Highlighting content using color, clear windows, blurry/sharp windows, lines, and other focus-and-context techniques helps the user visually focus on a selection of the content within a larger document [Kelin]. A mask that reduces contrast is more effective, and can be created with as little as 12 percent of pixels screened out to produce a strong effect. Such scrimming of the less relevant part of a webpage provides attention cues to relevant information, and yet allows any other information on the page to be accessed at any time. Other methods, such as using thin lines onscreen connecting content, have been effective in expediting search tasks on a page for users [Steinberger]. However, the examples used in this study could be categorized as complex data visualizations, and a technical user was assumed. A blend of all techniques is employed on commercial webpages, sometimes in combination with grayed-out areas, as well as hand-drawn lines directing attention within the masked area. Various online shopping pages have marked current steps on a check-out form in bold or a bright color, conducting users through the page.



**FIGURE 38 SCRIM IN USE HIGHLIGHTING THE ELIGIBILITY CHOICE. THE ARROWS BELOW IT ADVANCE THE OVERLAY TO THE NEXT SUGGESTED ITEM. THE WHOLE PAGE IS ACTIVE EVEN WHERE NOT IN APERTURE.**

Analog methods for focusing attention have been created in the past that contribute to the ease of reading. One example is our magnifier described above that can be slid down the ballot to the election contest a voter is considering. The means of directing a user's attention in voting has also been explored without a mediating layer, namely by manipulating the location, size, and grouping of candidate names and selection points in the Low Error Voter Interface described above.

### 6.1.4 Translucent Overlay – Prototype

Scrim is a tool with which annotations can be added to website pages or forms using the Chrome browser. Administrators designated to improve websites can train themselves to use it with a provided instructional video in a few minutes.

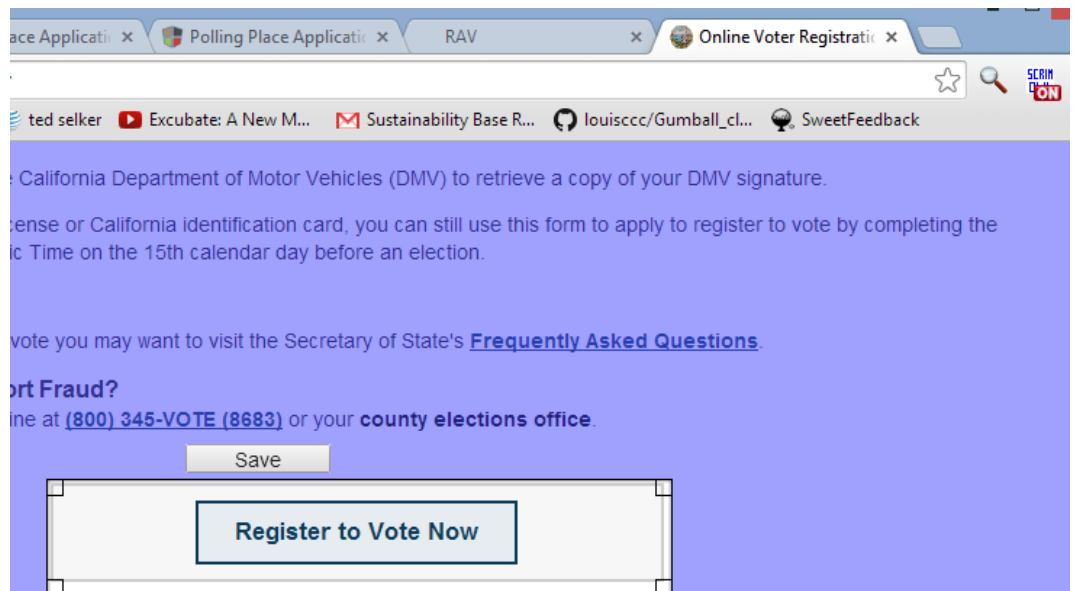
Scrim was designed as a simple quick way of stepping a user through a set of steps on a webpage. It follows the process first introduced in the IBM OS/2 SmartGuides interface. The goal of improving the accessibility of a registration site is achieved. The primary objective of Scrim's design is that it preserves the generality of the page, allowing users to orient themselves without changing the layout, color scheme, or content of the page. As such, it is a technique applicable to any webpage.

The Scrim software is an extension for the Chrome browser, programmed in Java for the purposes of prototyping. The software implements a layer over the page through Cascading Style Sheets (CSS) [CSS] called a canvas. The

experimental prototype works in Chrome and saves the scrim as a browser cookie. This approach could be extended to work for other major web browsers such as Firefox, Internet Explorer, or Safari.

An automated scrim was also made that parses and adapts a scrim to a sample ballot in a web browser. It highlights individual races, not individual candidates, to avoid supporting bias for the first candidate in a race.

An unusual quality of such a software tool is its ability to improve website interaction after the site is already launched and its potential value in helping users navigate existing online content. We expect that this kind of annotation could be useful for consumer and/or broader technical applications, where a low-cost, low-training software add-on would allow vendors to create a template for users. For instance, Scrim can work as a tutor conducting listeners through a complicated training document to help direct listener focus.



**FIGURE 39 SCRIM OVL "ON" IN CHROME TOOLBAR. THE APERTURE BOX IS HIGHLIGHTING THE REGISTER TO VOTE NOW BUTTON ON THE WEBPAGE. THE HANDLES ON THE CORNERS ALLOW RESHAPING THE APERTURE. THE SAVE BUTTON IS SELECTED TO MOVE TO THE NEXT BUTTON TO HIGHLIGHT.**

### 6.1.5 Translucent Overlays - Interactive Pages

With the registration scrim example, the web document is active and changes as the user inputs relevant information. This creates an additional need for adapting to the document as it changes. For instance, dialog boxes on a webpage link to other pages that can also be given Scrim translucent overlays.

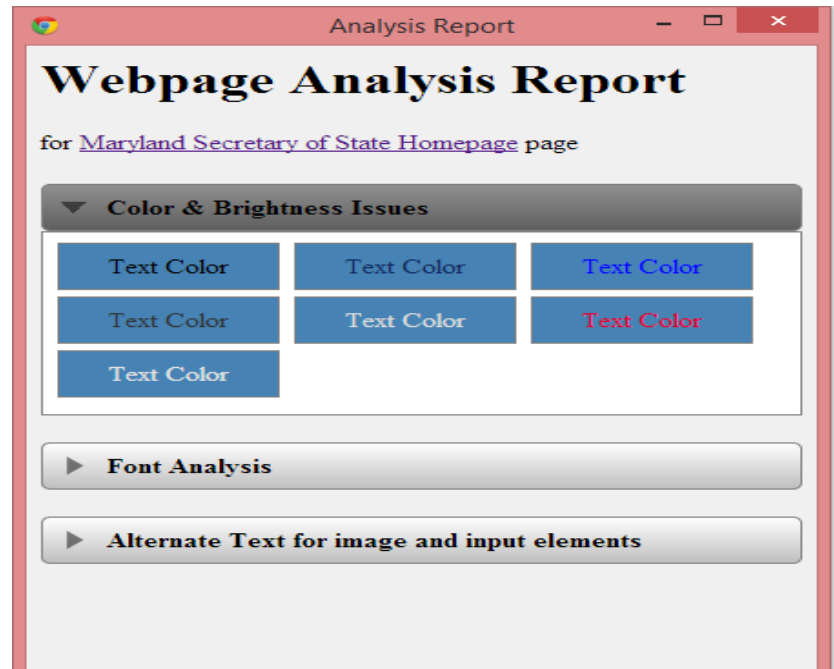
### 6.1.6 Translucent Overlay – Summary

The Scrim Chrome extension enables translucent-overlay stepping support for any webpage. Scrim was made as a system that allows a trainer to graphically select and highlight sequentially important places on a webpage. Scrim then helps a user step through a process while not stopping them from selecting any part of a page at will. Scrim can be used to help focus attention for people with cognitive disabilities. It is a way of testing and improving webpage usability without reprogramming it. A version of it automates the training phase for ballot-like pages if needed. We hope this app is used to validate and improve accessibility improvements for registration, polling-place location finding, and will be used to highlight progress in marking sample ballots. Security issues are important and the authenticity of the scrim must be established to assure that a rogue scrim isn't influencing a voter in some way.

## 6.2 Automated website Analysis for Visual Design (First Prototype—Mike Vrooman; Current System—Shama Hoque)

### 6.2.1 Website Analyzer – Summary

Many aspects of website design can impact readability and comprehension of tasks. Some of these aspects include color choices, font choices, font style and size, and alternate text for image and input elements. This section discusses an automated tool that shows user accessibility problems that may be encountered on their webpages. This Chrome plugin puts up a separate window that shows font number, size statistics, color contrast choices, and alternative metadata that might easily be changed to improve webpage accessibility. This system is based on a student project conducted by Mike Vrooman during an accessible voting class taught by Ted Selker and Dan Gillette at CMU-SV. A video of the website Analysis is available for viewing at



**FIGURE 40** WEBPAGE ANALYZER SHOWING COLOR TEXT CONTRAST USES ON PAGE: BLUE ON BLUE IN THIS CASE IS TOUGH TO READ.

<sup>4</sup><https://www.dropbox.com/s/6emue4akikn1o11/Website%20Analyzer%20Quick%20Demo.m4v> .

### 6.2.2 Website Analysis - Introduction

The primary objective of this project is to provide a way to analyze voting information websites in order to find ways in which they can be improved to be accessible to as many people as possible. Many systems have been made to analyze webpages. These systems, unfortunately, are hard to interpret or present problems that are difficult to address (see <http://www.w3.org/WAI/ER/tools/complete> for a list of these tools). The RAV Website Analysis System checks for color scheme contrast issues, brightness issues, and will also analyze text formatting in regard to font type, style, and size. While issues identified by the tool should not solely be used in order to initiate changes to a website's design, it can provide a great starting point for discussion and the review of a website's design.

### 6.2.3 Color and Brightness

When a webpage is being analyzed, the CSS for each element is inspected and passed through an algorithm to calculate the difference in color and the difference in brightness. This is done through a formula provided by the W3C for suggested techniques for analyzing webpages.

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<sup>4</sup>Mike Vrooman's early version and documentation available at <https://cmu96772.wordpress.com/studentwork/mike-vrooman/>

Brightness is evaluated as:  
 $((\text{Red} * 299) + (\text{Green} * 587) + (\text{Blue} * 114)) / 1000$

Color difference is calculated as:

$(\max(\text{Red1}, \text{Red2}) - \min(\text{Red1}, \text{Red2})) + (\max(\text{Green1}, \text{Green2}) - \min(\text{Green1}, \text{Green2})) + (\max(\text{Blue1}, \text{Blue2}) - \min(\text{Blue1}, \text{Blue2}))$

When brightness values are below 125, the W3C indicates there is a potential problem with the color choices. Similarly, color differences of less than 500 indicate a potential problem in the color choices. While these numbers give a scientific way to analyze viewability, people don't find the actual numbers to be meaningful in deciding whether or not a color choice was poor. The tool uses these numbers on the backend in order to determine which color combinations will be displayed to the user, but the numbers won't actually be shown.

#### 6.2.4 Font Type

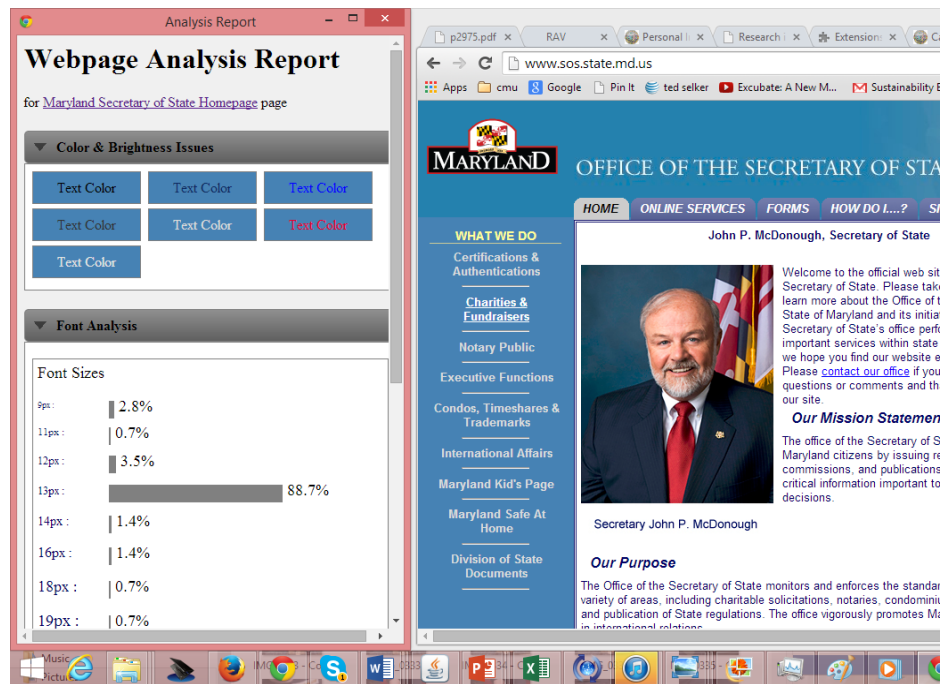
The question of whether to use a sans-serif font or a serif font for websites will elicit arguments for both sides. Some of the common arguments revolve around serif fonts allowing letters to be visually combined to form a word and allow better distinction between characters. However, on low resolution screens with a low pixels-per-inch (PPI) count, serif fonts may not render smoothly. Modern monitors support much higher PPI now and can render serif fonts without noticeable pixilation, even with small fonts. However, there are still low-quality monitors in use by people today and these users should also be taken into consideration. While not making a recommendation for serif vs. sans-serif, it is just as important to pick a font style and be consistent. Switching between many font styles will make a page harder to read.

#### 6.2.5 Font Style

The style of text on a website can be set to normal, italics, and oblique. Text written in italics will use a completely different glyph to represent a letter. This can make it harder to recognize the letters when reading text. Because of this, italic font usage should be minimally used. Oblique text will use the same glyphs as normal text, except the characters will be slanted. This text can also be difficult to read if it is overused.

#### 6.2.6 Font Size

The distribution of font sizes can also be reviewed in order to identify the overuse of small text. The W3C accessibility guidelines recommend using an 18 point or 14 point bold font. This can also be represented as a 1.5cm or 1.2cm bold font.



**FIGURE 41 WEBPAGE ANALYZER SHOWING FONTS USED ON PAGE: WELL OVER 90% ARE SMALLER THAN READABLE.**

While not measured by this tool, the guideline also states that text should be able to zoom to 200%, the default size without causing display issues or requiring the user to scroll off the screen in order to read the text. As tablets are being used more frequently, meeting this scaling recommendation will be an important feature of websites.

### 6.2.7 Technology Used

RAV's first automation tool was built using C# in a Microsoft Windows environment. A third party plugin written by Juicy Studio called 'Color Contrast Analyzer,' was used to calculate color and brightness levels. The open source framework 'White' was used to control the plugin. The open source framework 'Selenium' was used to control the browser and

analyze the final HTML created by the plugin-based system; it directly interacts with a web browser and can be interactive. It can process an entire page in less than a second. As a limitation, it is restricted to the browser it was made for (prototype was for Firefox, final version is for Chrome).

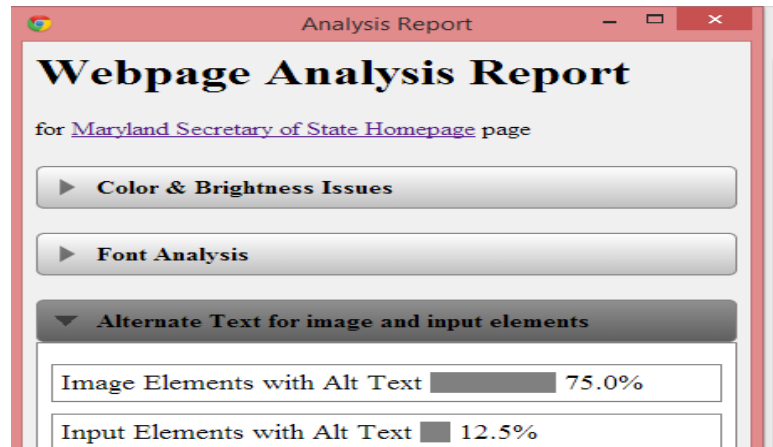
The Selenium framework's advantage is that it will work with all of the popular browsers available today. It is a widely used framework and isn't limited to any particular operating system or programming language. The current code could easily be migrated from C# to Java, Ruby, or Python, with just syntax changes. Selenium does not have direct access to the document object model created by the web browser and uses JavaScript to access the page. This results in page analysis taking up to several minutes to process. When testing a page in Firefox with 500+ unique web elements it took 115 seconds to process, while Chrome was able to process the page in 45 seconds. Updating the code to a multithreaded approach resulted in only a 10% performance gain. Chrome processed the page in 41 seconds and Firefox was taking about 99 seconds to process the page.

A second version was built in JavaScript and JSON for Chrome to better integrate a user interface and eliminate performance problems. The current extension is written in JavaScript and can be downloaded at [http://researchinaccessiblevoting.bitbucket.org/website\\_analyzer.zip](http://researchinaccessiblevoting.bitbucket.org/website_analyzer.zip).

### 6.2.8 Web Analyzer Going Forward

Currently the tool will display results in real time. Adding the feature of storing the results would allow conclusions to be made about a large sample of websites. For example, as bad color combinations are identified, checks could be done against all analyzed websites in order to see how frequently similar combinations are being used. Other areas of interest could be analyzed, such as checking for alternate text for image links. Different areas of keyboard accessibility could be automated. As the user tabs through the controls, a comparison of an image of the webpage before and after tabbing should show a visible change in selection. As the selection changes, the program can look for expected transitions, such as left-to-right, or right-to-left and down, but from right-to-left and up as unexpected and unacceptable, unless it is restarting to the beginning of the page. This area would require research to find the right patterns to look out for as indicators of a poorly designed page. Also, we would love to integrate usage evaluation tools. Tools that allow users to show how complex mouse paths are through a webpage, for example, would help developers reevaluate where to put buttons and fill-in windows.

We can imagine integrating Scrim with this tool to make a suite of solutions for analyzing and reducing impediments for individuals with disabilities. The approach presented here is a post hoc solution. We would be even more enthusiastic if typical program development suites used for web design and web design tools can be enhanced to encourage designers to



**FIGURE 42 WEBPAGE ANALYZER SHOWING “ALTERNATIVE TEXT AND IMAGE” EVALUATION**

The image shows the webpage analyzer window with banner buttons: Color & Brightness, Font Analysis, and Alternate Text for Image and Input elements. The “Alternative text for image and input elements” is selected revealing that image elements with alternate text at 75% and input elements with alternate text at 12.5%.

test using accessible techniques. web designers could permanently embed code in the website, instead of using a temporary plug-in or add-on to the browser. The software could be turned on or off by the user as needed.

## 7. Wii-based Voting

### 7.1 Wii Voting – Summary

Ying-Chuan Liu and Minh Pham created a voting system that utilizes the Wiimote, a remote game controller for the Nintendo Wii game console system, in an accessible voting class taught by Ted Selker and Dan Gillette at CMU-SV<sup>5</sup>. The system is a platform to explore novel gestural and button selection options for voting with disabilities. Several users felt comfortable and would recommend using a Wiimote as a voting device. However, more exploration is needed to explore its general usability for backgrounds and the disabilities it might address.

### 7.2 Wii Voting – Introduction

Researchers have proposed using visual and audio assistances to help the disabled cast their ballots. However, there are no specific solutions that are broad enough to cover the entire disability population. This project explored a portable controller with multiple input and feedback alternatives. The Wiimote is a flexible movement-capturing interface that utilizes the 3D motion-capturing controller in the Wiimote to provide a rich voting experience.

A Wiimote provides multiple interfaces for interacting with users, including buttons, gestures, and vibrations [Wiimote]. With their growing popularity, Wiimotes are inexpensive and available and widely used in various applications. One important feature of the Wiimote is its motion-sensing capability. Specifically, in the gesture recognition area researchers tried to utilize this capability of the Wiimote to evaluate human activities. For example, Kiefer used the Wiimote as a musical controller [Kiefer] and assessed its usability.

These interfaces could provide a voting system to serve people with sight and/or hearing impairment because they could provide prosthetics for either visual or hearing abilities.

### 7.3 E-Voting System Using Wiimotes

The Wii voting system divides a voting process into five stages: Welcome, Introduction, Vote, Review, and Confirm [Figure 45]. The Welcome stage gives the user a general idea of what the election is all about, and instructions are given in the Introduction. In the Vote stage, the user is able to browse all the candidates with their basic information, and then make a vote. During the Review stage, the user is able to view his or her voting result before sending out the ballot. Once the user Confirms the voting decision, the process completes and the user is not able to go back and change the result. To travel among the five stages mentioned above, the following command set is used:

1. Go to the next stage
2. View the previous candidate
3. View the next candidate
4. Select the candidate
5. Deselect the candidate
6. Confirm the decision

Commands	Gestures	Buttons
Next Stage	Button B	Button B
Previous Candidate	Swipe Left	Button Left
Next Candidate	Swipe Right	Button Right
Select Candidate	Swipe Down	Button Down
Deselect Candidate	Swipe Down	Button Down
Confirm	Swipe Down	Button Down

**FIGURE 43 A DEMONSTRATION MAPPING BETWEEN COMMANDS AND INPUT MESSAGES**

<sup>5</sup> <https://cmu96772.wordpress.com/studentwork/kate-liu/>



## 7. Wii Voting system Input Interface

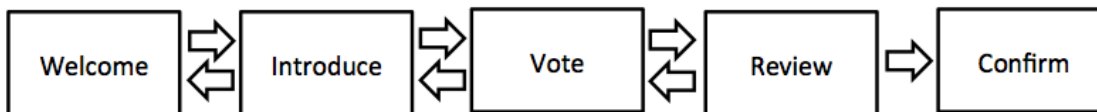
A Wiimote provides a variety of methods for interaction. The voting prototype focused on buttons and gestures. To reduce the learning curve, gestures were limited to just four: left, right, down and the B button. In this scheme, left represents back while right represents next.

Pressing the left button or a left swipe gesture is used to navigate to the previous page, while button right and swiping right is used to switch to the next page. Additionally, pressing the down button or a down gesture selects or deselects an item. Figure 43, we define the gestures and buttons that individually map to the commands mentioned in the previous section.

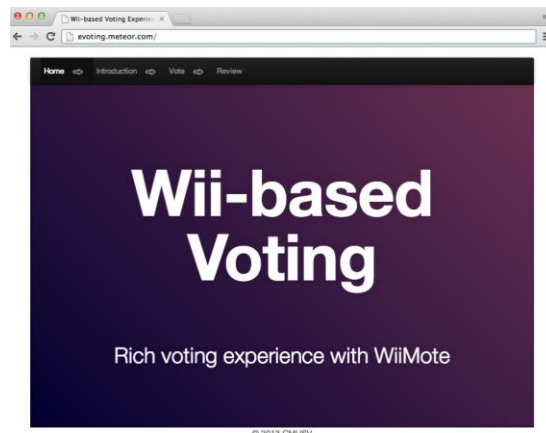
To indicate what the user can do to make selections and what selections they have done, output shows the user on the screen, in sound or through vibration. Individuals with visual impairment are able to receive auditory feedback, while individuals with hearing impairment can receive feedback through vibrations. Figure 44 shows audio instructions that individually map to the commands.

Feedback	Audio
Next Stage	Next Page
Previous Candidate	Back
Next Candidate	Next
Select Candidate	Vote
Deselect Candidate	Cancel
Confirm	Send

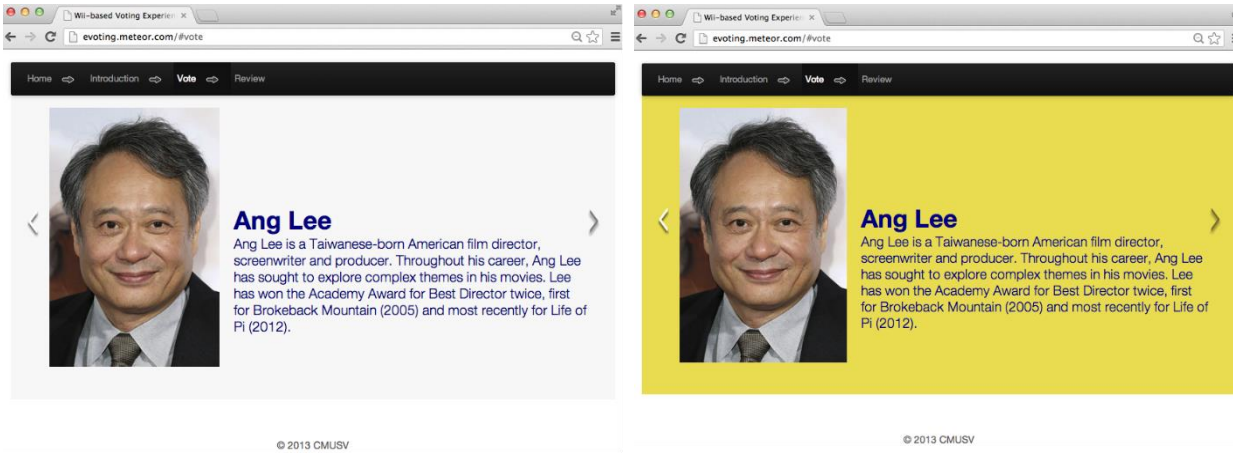
**FIGURE 44 A DEMONSTRATION MAPPING BETWEEN COMMANDS AND OUTPUT FEEDBACK**



**FIGURE 45 THE WII VOTING PROCESS**



**FIGURE 46 THE ENTRY PAGE FOR WII VOTING**



**FIGURE 47 COLOR CHANGE INDICATES USER SELECTION IN WII VOTING**

The implementation of the voting system is divided into two parts: website and Wiimote connection. The website uses HTML, JavaScript and CSS to implement the UI mockup illustrated in the previous section. The website is deployed to the Meteor environment. On the Vote page, the user is able to browse all candidates and related information. When the user casts a vote, the background color will change to notify the user [Figure 47]. The Wiimote to-laptop-communication is managed by BlueCove 2.1 [Bluecove] to set up connection between the computer and the Wii. WiiuseJ [WiiuseJ] and JavaFx [JavaFx] are used to program the Wiimote to trigger its buttons, gesture detection, and vibrations. A video of how it works can be found at [https://www.youtube.com/watch?v=O0D2ZzOhWFY&feature=youtube\\_gdata\\_player](https://www.youtube.com/watch?v=O0D2ZzOhWFY&feature=youtube_gdata_player).

The voting system proposed in this section is aimed at people with physical limitations, sight, and/or hearing impairment. We invited four participants who have slight visual impairment to test our system. The participants are all far-sighted people over 50. The pilot users were more concerned with font size than other graphic features such as colors, and layout.

The pilot users were satisfied with the sensitivity of gesture recognition, and they felt that the feedback could prevent errors, such as voting for the wrong candidates. Among the three types of feedback, initial users preferred visual and auditory aides to haptic feedback. Pilot users were divided as to recommending the Wiimote; a formal experiment could follow with people with particular disabilities to further validate the approach.

#### 7.4 Wii Voting - Conclusion and Future Work

Wiimote voting is a demonstration of how today's Commercial, Off The Shelf Technology (COTS) could offer new affordances that offer a range of opportunities for voting with physical and perceptual disabilities. The system worked well in demonstrations and was tried by 4 users. The interesting demonstrations for this work would come with experimenting with individuals with tremor, Parkinson's, multiple sclerosis, etc. Refining the platform with such experiences could improve and simplify the interface. Currently, the demonstration interface provided by the platform provides buttons and gestures as the input interfaces, and applies sounds and vibrations to be the feedback. A next version of the Wii-based voting system may merely focus on one input interface and one feedback source.

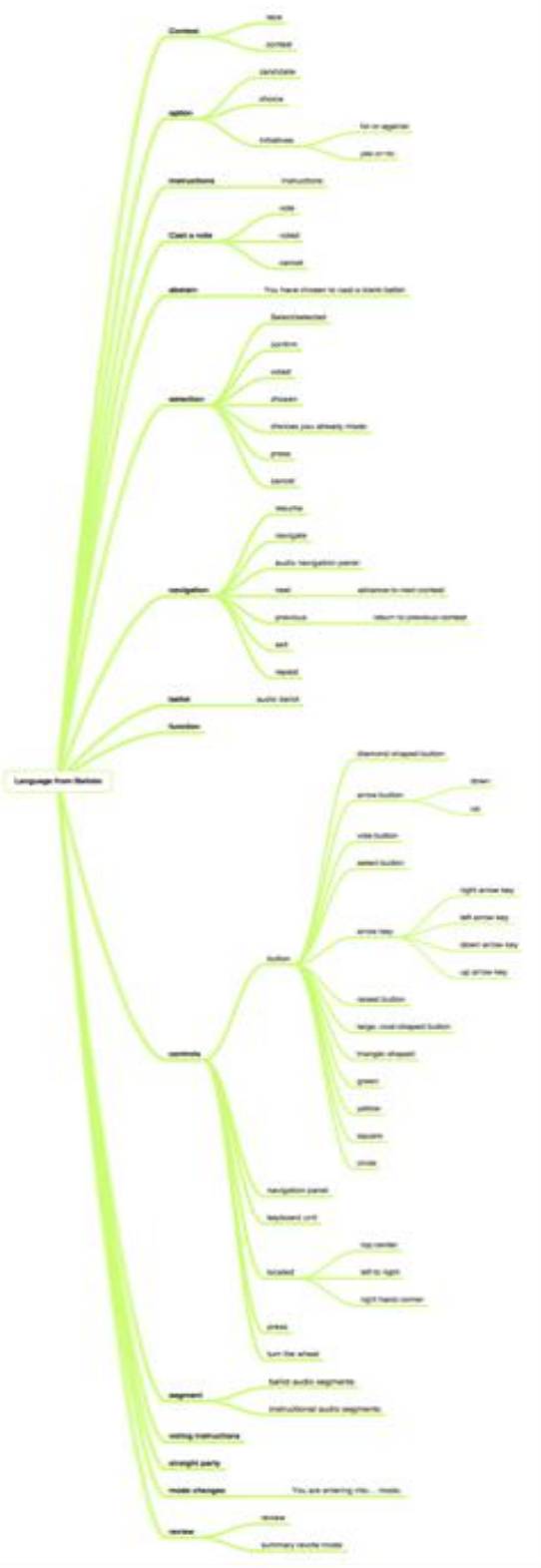
## 8. Other RAV Work

As well as the research and teaching work described above, RAV also participated in nationwide voting technology discussions, created policy proposals, participated in nationwide forums on voting with disabilities run by NIST, the Election Center, and others. We began work on 3D audio selection. We performed small exploratory projects including considerate response, more efficient list browsing, Earcon design, and more efficient ballot reviews for individuals with disabilities. RAV also explored systematizing audio commands to simplify the wording. An analysis for instruction syntax

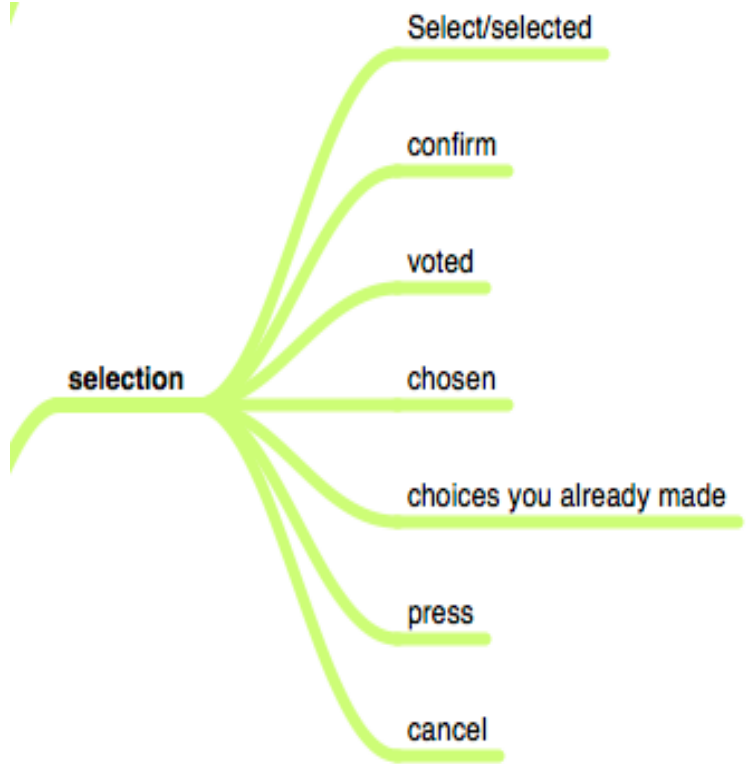
and word choice was made for several vendors' voting machines. Continued work in this area could greatly simplify audio voting. [Figure 48, 49]

RAV drafted a proposed list of simple improvements that could be implemented in the run-up to the 2012 election shown in the appendix. Such lists that we made and distributed from the Voting Technology Project helped in past elections. In the end, RAAV was not convinced the list shown in the appendix shortly before the election would help.

RAV substantiated the value of running project-based graduate-level classes to explore technology for voting with disabilities. The Wiimote, the first prototype of the RAV Webpage Analyzer, and a first prototype of the Voting Place Simulator were made with students in a RAV-driven CMU graduate program class called Extreme Interfaces: Voting with Disabilities. This class was partially motivated by the success that came from a Voting Technology class Ted ran earlier at MIT. In that case, Mathew Hockenberry worked with us to invent Abrievicons, which shorten audio voting [Hockenberry]. He also demonstrated that mouse buttons were an improvement over standard specially-designed accessibility paddle buttons for speed and accuracy of accessible voting. RAV is convinced that such mouse buttons are an excellent alternative voting-input approach. We conclude that exploratory projects in graduate courses on technology for voting can be extremely productive.



**FIGURE 48 THIS DIAGRAM SHOWS THE DIVERSITY OF TERMS USED FOR COMMANDS IN DIFFERENT COMMERCIAL AUDIO**



**FIGURE 49 THIS DIAGRAM REPRESENTS AN ANALYSIS OF THE VARIOUS WORDS USED IN DIFFERENT AUDIO VOTING SYSTEMS FOR A SELECTION ACTIVITY. THIS IS AN EXPANSION OF THE 6<sup>TH</sup> TERM EXPANSION OF FIGURE 48.**

## 9. RAV Final Report Conclusion

The work of the RAV offers a roadmap of technical solutions that can improve voting for individuals with disabilities. To ensure that people are voting privately, they must vote in public. To vote, we must register, in many cases online. RAV has made tools [Scrim, Web Analyzer, LEVI] to help web designers be aware of and solve many problems individuals with disabilities face online. To vote independently in public, polling place operations have to work. Voting independently at public polling places is rarely easily successful for our population. RAV hopes to make real and lasting improvements to voting for individuals with disabilities. We have made the Polling Place Support Tool to solve many polling place problems not adequately addressed today. Many disabilities create difficulties for paper. We have created physical structuring, illumination, and magnifying prosthetics to explore and ameliorate many problems individuals with disabilities have working directly with paper. People make mistakes marking selections, whether marking up a sample ballot or marking a ballot to print out; RAV introduces graphical, audio, and physical interface voting alternatives. With more development and testing, RAV solutions can tremendously increase individuals with disabilities' success in voting. RAV explorations could convincingly eliminate millions of errors made in voting throughout the country. We expect they could also reduce recordable residual votes significantly.

The number of individuals with disabilities that could be disenfranchised in voting is not an insignificant portion of our population. We are the disabled and the not currently disabled. As well as addressing disability access, the technology we create can help voters universally. RAV has worked to make real and lasting improvements to voting for individuals with disabilities. The RAV graphical interface solutions are being used by researchers and are in plan for Maryland's overseas voting approach. RAV paper ballot Magnifier Illuminator Support (MI-S) is being tested. RAV audio interface improvement work has been published, and is available. RAV webpage access tools are available and being considered by various voting jurisdictions. The RAV Polling Place Support Tool is in consideration by large voting jurisdictions as well. With continued support, this work could help cement the impact of these solutions academically and practically.

RAV has shown improvements for universal access across a range of today's voting scenarios. They range from solutions that can be implemented immediately, to ones that provide direction for next-generation voting systems. Additionally, all software prototypes will be released into the public domain, allowing other researchers to build on the work.

The Research in Accessible Voting project focused on creating technology to address a variety of disabilities issues in voting. In a technological age, technology creation can make profound improvements on policy creation. Some years ago the person responsible for deciding what technology to use for voting in China contacted Ted Selker. He wrote a very long paper including the work we had done and asked for comments and interaction. After about a year, he decided to create a new kind of optical scan system for China: one that would rely only on the text shown on the ballot that their voter viewed. Instead of using an internal ballot module, it scanned the physical ballot to establish what races and decisions the person viewed for their selections. Interestingly, by consulting with the Voting Technology Project, they established this improved practice many years before anyone in the USA had such a secure and accurate way to vote with a paper ballot.

Policy creation should not be limited to Common Off The Shelf technology. Unlike 2000 when the country began focusing on voting technology problems, today almost everyone owns a cellphone with a camera and a GPS in it. Unlike 2000, mobile tablets and laptops are available for most data-oriented jobs. The implications of pervasive computing must be considered in approaches for all citizen activities. Now researchers are defining and describing a future in which sensors, analytics, and effectors make up the Internet Of Things (IOT). This IOT too, is transforming how people and technology work together. How will cameras and people sensors everywhere impact voting? The need to continuously fund technology research in service of policy decisions is critical today. The RAV work promotes the value of continued, non-vendor research in technology that can improve access, integrity, and accuracy. Specifically, the value of creating technology for voting with disabilities is urgent. Early attempts to incorporate new web technologies for election services may have been hastily planned and executed. The return to paper ballots in many jurisdictions have, in many cases, left individuals with disabilities without working systems that allow them to succeed in voting on their own.

The Research in Accessible Voting (RAV) project has endeavored to provide innovations that can offer new solutions for policy that can improve voting for individuals with disabilities. Historically, policy decisions have been focused on available resources, problems, and technical systems. Such analysis of the 2000 election showed that problems with registration, polling place operations, and ballot design were the main causes of lost votes [Alvarez]. The following few years, however, showed technologists dominating the conversation by pointing to their predictions that *potential problems* in computer security could be even more dangerous than the *known* problems. The NSF and others responded by funding the concerned technologists. We are now in a place where technological progress is as important as cultural readiness for change. Our research has tried to strike a balance, creating technology that could solve measured and prospective problems for individuals with disabilities. We hope that this report helps show how investment in technological solutions can help improve policy options for the US.

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## 11. Appendicies

### 11.1 Write-in Experiment Materials

Participant	Order	Condition 1: Single Tap			Condition 2: Four Keys			Condition 3: Two Keys		
		1 <sup>st</sup> Trial	2 <sup>nd</sup> Trial	Average	1 <sup>st</sup> Trial	2 <sup>nd</sup> Trial	Average	1 <sup>st</sup> Trial	2 <sup>nd</sup> Trial	Average
1	1, 2, 3	34	36	35	34	40	37	45	42	43.5
2	1, 2, 3	37	38	37.5	43	36	39.5	30	40	35
3	1, 2, 3	46	49	47.5	40	43	41.5	41	39	40
4	1, 2, 3	40	38	39	47	49	48	36	40	38
5	1, 2, 3	37	41	39	56	58	57	39	--	39
6	1, 2, 3	51	41	46	--	--	--	--	--	--
7	1, 2, 3	52	49	50.5	--	--	--	--	--	--
8	1, 2, 3	55	53	54	--	--	--	--	--	--
9	1, 2, 3	55	41	48	--	--	--	--	--	--
10	1, 2, 3	38	42	40	--	--	--	--	--	--
11	2, 3, 1	31	35	33	--	51	51	48	37	42.5
12	2, 3, 1	27	40	33.5	50	60	55	38	32	35
13	2, 3, 1	39	36	37.5	63	65	64	35	43	39
14	2, 3, 1	42	40	41	63	58	55.5	46	50	48

15	2, 3, 1	32	32	32	--	53	53	40	39	39.5
16	2, 3, 1	44	53	48.5	66	61	63.5	42	55	48.5
17	2, 3, 1	41	36	38.5	69	68	68.5	39	48	43.5
18	2, 3, 1	36	36	36	62	48	55	25	39	32
19	2, 3, 1	--	--	--	64	65	64.5	--	--	--
20	2, 3, 1	--	--	--	64	50	57	--	--	--
21	3, 2, 1	--	--	--	--	--	--	49	44	46.5
22	3, 2, 1	--	--	--	--	--	--	48	32	40
23	3, 2, 1	--	--	--	--	--	--	50	45	47.5
24	3, 2, 1	--	--	--	--	--	--	39	37	38
25	3, 2, 1	--	--	--	--	--	--	44	40	42
26	3, 2, 1	49	36	42.5	65	55	60	45	50	47.5
27	3, 2, 1	34	33	33.5	41	42	41.5	40	45	42.5
28	3, 2, 1	53	52	52.5	45	46	45.5	38	49	43.5
29	3, 2, 1	40	--	40	53	58	55.5	49	48	48.5
30	3, 2, 1	--	--	--	--	--	--	48	40	44

**FIGURE 50** DATA SHOWING THAT THE SIMPLER TWO-KEY INTERFACE ALLOWED PARTICIPANTS TO COMPLETE TASKS FASTER THAN WITH FOUR KEYS, BUT NOT NECESSARILY FASTER THAN TYPING ON A KEYBOARD.

## 11.2 Magnifier Experimental Materials

### 11.3.1 IRB Protocol

#### Study Title

#### Usability Testing of New Election Technologies

Complete each section. When a question is not applicable, enter "N/A". Do not leave any sections blank.

#### 1. Purpose

Provide a brief explanation of the proposed research, including specific study hypothesis, objectives, and rationale.

This research is intended to explore the utility of new ways to focus the visual attention of voters when voting on paper, marking ballots online and registering to vote. The prototypes to be tested include a physical reading magnifier for paper ballots and a website scrim (a semi-transparent filter with a dynamic rectangle cutout that exposes only certain sections of a website at a time) for online materials. The hypothesis is that these aids will make it easier for individuals with less than average vision and/or learning disabilities to focus on tasks, perceive content and work accurately, leading to faster task completion times. The rationale for this hypothesis is that the existing voting materials (such as election ballots and online registration sites) provide information a manner that is too free-form and crowded with content; our prototypes are intended to simplify the browsing of such materials. The overall objective is to garner objective and qualitative data that will inform the next iteration of our designs.

#### 2. Background

Give relevant background (e.g., summarize previous/current related studies) on condition, procedure, product, etc. under investigation, including citations if applicable (attach bibliography in Attachments section).

Voting can be confusing and election materials difficult to work with (Alvarez, R., Ansolabehere, S., Antonsson, E., Bruck, J., Graves, S., Siegel, J., Palfrey, T., Rivest, R., Selker, T., Slocum, A., & Stewart III, C. (2001) Voting: What is, what could be. Caltech - MIT Voting Project.)( Selker, T. (2004) Processes can improve electronic voting: a case study of an election. Caltech/MIT Voting Technology Project.). This can be especially true for individuals with reading disabilities and poor eyesight. Previous research has shown that focusing voter attention and providing larger text can be helpful (Selker, T., Goler, J., Wilde, F. (2005) Who does better with a big interface? Improving Voting Performance of Reading Disabled Voters. Caltech - MIT Voting Project.). This study is intended to test an improvement on voting magnifiers with a freestanding prototype specifically intended for use with paper ballots. The study will also test a new web-based tool to focus voter attention when registering to vote online by creating an interactive overlay system that exposes a web-form's content sequentially to the user without modifying the underlying webpage.

#### 3. Collaborative Research

a) If any non-UCB institutions or individuals are engaged in the research, explain here.

None are currently engaged.

b) If any non-UCB institutions or individuals are collaborating in the research, complete the table below and attach any relevant IRB approvals in the Attachments section.

Non-UCB institutions

Previous

Next

#### 4. Qualifications of Study Personnel

a) Explain expertise of Principal Investigator, Student/Postdoc Investigator, Faculty Sponsor (if applicable), any Co-Investigators or other key personnel listed in the application, and how it relates to their specific roles in the study team.

Eric Paulos is the Director of the Living Environments Lab, Co-Director of the CITRIS Invention Lab, and an Assistant Professor in Electrical Engineering Computer Science Department at UC Berkeley where he is faculty within the Berkeley Center for New Media (BCNM). His areas of expertise span a deep body of research territory in urban computing, sustainability, green design, environmental awareness, social telepresence, robotics, physical computing, interaction design, persuasive technologies, and intimate

media. Eric received his PhD in Electrical Engineering and Computer Science from UC Berkeley where he helped launch a new robotic industry by developing some of the first internet tele-operated robots including Space Browsing helium filled blimps and Personal Roving Presence devices (PRoPs). As PI of this study, his experience creating and testing novel interfaces will allow him to provide valuable insight into the design of the prototypes and meaning of collected data.

Ted Selker is a visiting scholar in the data and Democracy Initiative at CITRIS, UCB. Ted spent 5 years as director of Considerate Systems research at Carnegie Mellon University Silicon Valley. He was also responsible for developing the campus's research mission, teaching HCI, Android product design, and research in voting with disabilities. Ted spent ten years as an associate Professor at the MIT Media Laboratory where he created the Context Aware Computing group, co-directed the Caltech/MIT Voting Technology Project, and directed the CIDI Kitchen of the future/ product design of the future project. His work in voting technology, as a designer and researcher, provides critical grounding for this project.

Dan Gillette is a visiting scholar in the Data and Democracy Initiative at CITRIS, UCB. He also is a member of the CITRIS Social Apps Lab, where he leads a product team creating PIC Your Future, a college readiness app funded by UCOP. Previously, Dan held research and teaching positions at Carnegie Mellon University, Stanford University, Mills College, and CSU Monterey Bay. Additionally, Dan was a cofounder and design principal at In World Solutions, a startup that provides virtual reality tools for the behavioral healthcare market. From 2002-2008, Dan was chair of the Innovative Technology for Autism Initiative. Dan holds a B.A. in human development from the Lesley College Graduate School, and an Ed.M. from the Harvard Graduate School of Education, with a concentration in cognitive science, psychology, and instructional design. Dan brings to this project two decades of experience designing and testing accessibility products.

### *11.3.2 Specific Protocol*

#### Subject Population

a) Describe proposed subject population, stating age range, gender, race, ethnicity, language and literacy.

The proposed population for this study will be students and staff of UC Berkeley who have a moderate vision impairment that affects reading, but is correctable with glasses and individuals with dyslexia and/or attention deficit disorder. The age range is 18 years and older. Gender, race and ethnicity will be representative of the available recruitment pool. Participants must be fluent in written English and able to follow spoken English instructions.

b) State total (maximum) number of subjects planned for the study and how many must be recruited to obtain this sample size. Explain how number of subjects needed to answer the research question was determined.

The number of participants sought is 10-16, which will provide a sample pool of 5-8 individuals that meet each the two main population groups for the study -- moderate vision impairment and learning disabilities -- and still provide some room for administration error. It is standard practice to conduct exploratory usability studies with 4-6 individuals, such as this one. The plan is to conduct rolling recruitment until we have successfully completed the study, meaning that we will not recruit a pool of alternate participants.

c) If any proposed subjects are children/minors, prisoners, pregnant women, those with physical or cognitive impairments, or others who are considered vulnerable to coercion or undue influence, state rationale for their involvement.

We will be recruiting individuals with mild-to-moderate learning disabilities, as this is one of the target populations for the study.

#### 6. Recruitment

a) Explain how, where, when, and by whom prospective subjects will be identified/selected and

approached for study participation. If researcher is subject's instructor, physician, or job supervisor, or if vulnerable subject groups will be recruited, explain what precautions will be taken to minimize potential coercion or undue influence to participate. See CPHS Guidelines on Recruitment for more information.

Recruitment will be handled by the distribution of flyers. Recruitment will begin in proximity to our office in SDH and extend to the distribution of flyers in other parts of campus if needed. Subordinates or current students of the research team will not be actively recruited. When a potential participant contacts the recruiter, a private discussion will take place in person, by phone or by email to determine if s/he is eligible for the study.

b) Describe any recruitment materials (e.g., letters, flyers, advertisements [note type of media/where posted], scripts for verbal recruitment, etc.) and letter of permission/cooperation from institutions, agencies or organizations where off-site subject recruitment will take place (e.g., another UC campus, clinic, school district). Attach these documents in Attachments section.

When meeting a potential participant, the following script will be used:

"Hi, I'm [recruiter's name]. I'm part of a team working on technology to make voting tasks easier for individuals with minor vision problems or learning disabilities. Would you be interested in participating in our usability study to assess these tools? It should take no more than 50 minutes and you will receive a \$25 gift card as a thank you for your participation."

If the answer is that would like to participate, the recruiter will provide a flyer. If the answer is no, the recruiter will thank the individual and say goodbye.

Another recruitment tactic will be email, sent to those known by the project with the intent of the message being forwarded. The following text will be used in the email.

"Ted Selker and Dan Gillette, visiting scholars in the Data and Democracy Initiative at CITRIS, are currently conducting a study to assess prototypes they have built to help individuals with minor vision difficulties or learning disabilities complete voting-related tasks, such as voter registration and voting with paper ballots. If you know anyone who might be interested in participating in this study, please forward this email and the attached flyer."

c) Will anyone who will be recruiting or enrolling human subjects for this research receive compensation for each subject enrolled into this protocol? If yes, please identify the individual(s) and the amount of payment (per subject and total).

No one conducting enrollment will have compensation tied to successful recruitment.

## 7. Screening

a) Provide criteria for subject inclusion and exclusion. If any inclusion/exclusion criteria are based on gender, race, or ethnicity, explain rationale for restrictions.

Since we are developing aides for individuals with minor vision difficulties that affect reading, as well as dyslexia or ADD, participants will need to have one of these conditions. Additionally, since this study focuses on reading tasks, all participants will be required to be fluent in written English and able to follow verbal instructions in English. Participants must be at least 18 years old, since that is the minimum age for voting in the United States and we are testing aides for voters. Self-report will be the means for verifying the participant meets the inclusion criteria.

b) If prospective subjects will be screened via tests, interviews, etc., prior to entry into the "main" study, explain how, where, when, and by whom screening will be done. NOTE: Consent must be obtained for screening procedures as well as "main" study procedures. As appropriate, either: 1) create a separate "Screening Consent Form;" or 2) include screening information within the consent form for the main study.

NA

## 8. Compensation and Costs

a) Describe plan for compensation of subjects. If no compensation will be provided, this should be stated. If subjects will be compensated for their participation, explain in detail about the amount and methods/terms of payment.

Include any provisions for partial payment if subject withdraws before study is complete.

When subjects are required to provide Social Security Number in order to be paid, this data must be collected separately from consent documentation. If applicable, describe security measures that will be used to protect subject confidentiality.

If non-monetary compensation (e.g., course credit, services) will be offered, explain how

Each participant will receive a \$25 gift card to Target or Starbucks (participant choice). Participants will communicate their choice when scheduling their participation in the study and cards will be given to the participants at the end of testing.

b) Discuss reasoning behind amount/method/terms of compensation, including appropriateness of compensation for the study population and avoiding undue influence to participate.

In previous, recent research studies done by investigators involved with this study, the amount of the gift card, and the related-vendors was deemed as an appropriate thank you for participation and of interest to the majority of potential participants.

c) Costs to Subjects.

NA

## 9. Study Procedures

a) Describe in chronological order of events how the research will be conducted, providing information about all study procedures (e.g., all interventions/interactions with subjects, data collection procedures etc.), including follow-up procedures.

1. Greet participant

2. Introduction: "Thank you for agreeing to participate in this study. Today we are testing some ideas for changing the way people vote. During this study we will ask you to answer some questions and ask you to complete a reading level test before you try the technology. You will then try to use a few different systems. Finally we will discuss the systems. The time required for the testing portion of the test should take less than hour. Do you want to continue?" (2 minutes)

3. Consenting (if not completed prior to testing) (10 minutes)

4. Demographic Interview: Age, gender, education level, voting history (when was the last time the participant voted and with what technology) need for reading glasses and learning disabilities (5 minutes)

5. Administer the easy CBM Passage Reading Fluency measure, grade 8, form 8\_2 (5 minutes)

6. Usability Test Administration: The order of the following conditions will be randomized and interwoven (ballot task/registration task/ballot task/registration task/ballot task).

A. Paper Ballot: The participant is asked to vote on three contests, two candidate and one proposition (the participant will be coached on which candidates to vote for and will be asked to vote his/her own opinion for the proposition) (5 minutes)

B. Paper Ballot with Magnifier: The participant is asked to vote on three contests, two candidates and one proposition using the prototype voting magnifier (the participant will be coached on which candidates to vote for and will be asked to vote his/her own opinion for the proposition) (5 minutes)

C. Online Ballot Marking with Scrim: The participant is asked to vote on three contests, two candidates and one proposition using an online ballot marker that resembles paper, but allows for the use of the scrim prototype (the participant will be coached on which candidates to vote for and will be asked to vote his/her own opinion for the proposition) (5 minutes)

D. Registration Site: The participant is asked to complete a subset of tasks on the Trust the Vote Project sample registration website (<http://va-demo.voterportal.trustthevote.org>) (5 minutes)

E. Registration Site with Scrim: The participant is asked to complete a subset of tasks on the Trust the Vote Project sample registration website (<http://va-demo.voterportal.trustthevote.org>) using the scrim prototype (5 minutes)

7. Post-testing debrief (10 minutes)

8. Thank participant and deliver gift card

b) Explain who will conduct the procedures, where and when they will take place. Indicate frequency and duration of visits/sessions, as well as total time commitment for the study.

The procedures will be conducted by Dan Gillette and Ted Selker in their office, room 462, Sutardja Dai Hall. Participants are only expected to complete one session, lasting 40-60 minutes. Testing will be scheduled



based on participant availability, with attempts to do back-to-back testing sessions whenever possible. Total time needed for administration of the procedures for all participants is estimated to be 16 hours.

c) Identify any research procedures that are experimental/investigational. Experimental or investigational procedures are treatments or interventions that do not conform to commonly accepted clinical or research practice as may occur in medical, psychological, or educational settings. Note: if the study only involves standard research or clinical procedures, enter "N/A" here.

N/A

d) If any type of deception or incomplete disclosure will be used, explain what it will entail, why it is justified, and what the plans are to debrief subjects. See CPHS Guidelines on Deception and Incomplete Disclosure for more information. Any debriefing materials should be included in the Attachments section.

N/A

e) State if audio or video taping will occur. Describe what will become of the tapes after the project (e.g., shown at scientific meetings, erased) and final disposition of the tapes.

Video recording will occur to record participant behavior during each experimental condition. The raw recordings will be copied to a hard-drive used to house experimental data at DDI and the original recordings will be deleted. The recordings will be kept in a locked cabinet in Dan Gillette's office and will be handed over to the director at DDI if he leaves UC Berkeley.

The recordings will be used by the researchers to review the test procedures and portions may be played at academic and governmental talks and conferences.

## 11. Alternatives to Participation

Describe appropriate alternative resources, procedures, courses of treatment, if any, that are available to prospective subjects. If there are no appropriate alternatives to study participation, this should be stated. If the study does not involve treatment/intervention, enter "N/A" here.

### 11.3 Wii Mote Experimental Materials

#### Demographic

Have you ever used any device that provides haptic, visual or sound feedback?	Yes or No
Have you ever used the Wiimote to use as a source of control?	Yes or No
What is your age range?	60-70, 71-80, 81-90, 91+
Have you ever used a computer based voting system?	Yes or No
Do you have any of the following impairment or uses any of these devices	Yes or No
Do you have any dexterity issues that may prevent you from using the Wiimote comfortably?	Yes or No
Graphic Does the layout remind you of any past voting system you used?	Yes or No
Where you able to read the text?	Yes or No
Did the color scheme and layout made it easier for you to navigate?	Yes or No
Did the picture of the candidates help when browsing for can date?	Yes or No
Given these new features that can be provided, which do you think would be more useful?	
Ability to enlarge the text, change the layout, or change the color scheme	

#### Feedback

Could you rank which feedback system was more important?	Haptic, visual, and sound
Was there any moment you wish the Wiimote gave a different feedback?	Yes or No
Do you feel that the gesture sensitivity needs to be more sensitive?	Yes or No
Did you feel the feedback system prevent any errors that may have occurred such as voting for the wrong candidates?	Yes or No
Do you know of any devices that provide feedback which you believe we should also look at?	Yes or No

## General

Would you prefer the new Wiimote voting system over the current voting system?	Yes or No
Would you use the Wiimote system overall if it was available at the next election?	Yes or No
On a scale from 1-4, 4 being comfortable, did the Wiimote felt comfortable to hold and used as a voting device? 1-4	
Would you recommend the Wiimote to anyone?	Yes or No

### 11.4 Making Voting Accessible for Election 2012

#### Twelve Quick Tips for Election Officials

##### Introduction

Voters with special needs are a large part of Presidential elections. The odds of a voter having a disability are about 1 in 5. About 1 in 7 voters will have a severe disability. These numbers indicate that approximately 20% of those participating in elections will have some form of special needs.

The most prevalent types of disabilities among all voters, (according to the US Census) are:

Difficulty standing	10.4%
Difficulty walking	9.8%
Cognitive difficulties	7.0%
Difficulty seeing	3.4%
Difficulty hearing	3.4%
Difficulty with speech	1.1%

##### Providing Accessible Information

- Prepare all voting instructions and all voting equipment to be used by all voters so that nothing else needs to be done for a voter with special needs. **NOTE: *The point here is to NOT wait until a special needs voter appears before preparing the voting equipment or the ballot and instead have it ready to go so that ANY voter can use the special needs provisions at any time. (can we provide a link to an exemplar?)***
- Work with state and local assistive technology groups to provide voting information, voting instructions, and equipment instructions in formats that can be easily used by individuals with disabilities. Look for alternative formats such as audio tools, video interpretations. **NOTE: *Voters with sight challenges cannot easily adapt PDF files for their use. (can we provide a link to a list of them ?)***
- For those with cognitive issues, provide simplifying graphics and easily understandable language. Meet with educators and/or disability advocacy organizations to assure that voting information and voting and equipment instructions can be clearly understood. **NOTE: *Because cognitive difficulties affect a significant portion of the population, developing instructions and information in easily understandable language at no higher than a sixth grade reading level is recommended. (can we provide a link to an exemplar?)***

##### Viewing the Polling Place from a Special Needs Approach

- Examine every polling place:
  - Can a voter in a wheel chair easily enter the polling place?
  - Is signage truly informative as to what is the most direct path for finding and entering the polling place?
  - Can entry doors be easily opened by any voter with limited strength?

- Use the tools developed to teach poll workers how to best approach and serve voters with special needs. (See Disability Etiquette from the Tennessee Disability Coalition).
- (See Election Center checklist on Accessibility ). Also see www.ada.gov/votingchecklist.htm
- Casting A Ballot
- If permitted in your state, make sample ballots available to voters while they are waiting to vote. This tool can help them prepare for the actual voting process.
- Simplify ballot layout and language, while still complying with state election law. **NOTE: Even though specific ballot language may be required by law, see if it can be simplified for comprehension. (can we provide a link to an exemplar?)**
- Be prepared for handling spoiled ballots or providing greater voting assistance. Be sensitive that some voters may not grasp what they need to do to vote successfully. **NOTE: Audio ballots increase the demand for memory and that can be a problem for anyone with cognitive issues.**
- Integrate Not Isolate
- Set up all special needs equipment so that it is ready for use by ANY voter at any time. **NOTE: The number one polling place complaint of voters with disabilities is that the accessible voting equipment is not ready to use and/or the poll workers don't know how to use it.**
- Train poll workers to greet all voters with a simple “Is there anything I can do to help you?”
- Ask area disability advocacy groups to provide greeters at polling places and/or provide additional trained assistance (if permitted by your state laws).

#### Finding Help from Government or Advocates

The U.S. Election Assistance Commission	<a href="http://www.eac.gov">www.eac.gov</a>
The U.S. Access Board	<a href="http://www.access-board.gov/links/disability.htm">www.access-board.gov/links/disability.htm</a>
List of disability organizations	<a href="http://www.disaboom.com/organizations">www.disaboom.com/organizations</a>
Neighborhood Legal List of organizations	<a href="http://www.nls.org/dislinks.htm">www.nls.org/dislinks.htm</a>
Disability Resources	<a href="http://www.disabilityresources.org/DRMreg.html">www.disabilityresources.org/DRMreg.html</a>
Research Alliance for Accessible Voting	<a href="http://www.accessiblevoting.org">www.accessiblevoting.org</a>
Civic Designing (Ballot Design Tips)	<a href="http://www.civicdesigning.org/fieldguides">www.civicdesigning.org/fieldguides</a>
Election Center – Accessibility Checklist	<a href="http://electioncenter.org/checklists.html">http://electioncenter.org/checklists.html</a>
Tennessee Disability Coalition	<a href="http://www.tndisability.org">www.tndisability.org</a>
(and list all the other RAAV partners sites)	