The Technology of Access: Allowing People of Age to Vote for Themselves

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I. INTRODUCTION

With changing cognitive abilities, an aging person's independence becomes an issue, and questions arise of whether he or she has the ability or the legal right to take part in some civic activities, such as voting. The question of voting among elderly populations has a legal dimension; in their article, *Voting by Residents of Nursing Homes and Assisted Living Facilities: State Law Accommodations*, Amy Smith and Charles Sabatino discuss how different states in the United States evaluate what assistive services should be provided to residents of nursing homes.[1] Eight states hand caregivers the power to vote for voters living in certain care facilities, and many states prohibit voters under guardianship from voting.[2] Yet guardianship does not necessarily preclude people from voting, as evidenced by a Maine 2001 case in which a ban against preventing persons under guardianship from voting was overturned on principle.[3]

This article, however, does not discuss the legal implications of voting for people of age. Rather, it focuses on the implications of technology on voting. The premise of this article is that technology's goal is to create access. In this context, *access* should be contrasted with *assistance*. Technology should facilitate anyone legally permitted to vote (access) without relying on help from another person (assistance). To the extent that election officials can remove the barriers to voting independence—such that the intentions of voters can be recorded, recognized, and understood—officials will reduce the need and complications of having another person in the voting booth or completing an absentee ballot for a voter.

Universal access is an important goal of technology. This article examines several evolving voting technologies and their impact on persons with cognitive and physical disabilities. The research described shows how many accessibility technologies designed for people of age could also improve the performance of the general voting population. The number of people who make mistakes in the voting population varies dramatically. One study showed that—depending on the technology used—between one-half and three percent of voter selections on a typical ballot are actually for an adjacent selection.[4]

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* This work was supported by John S. and James L. Knight Foundation and Carnegie Corporation of New York. Special appreciation is due to Bob Parks for his tireless and helpful editing.

1. Amy Smith & Charles P. Sabatino, *Voting by Residents of Nursing Homes and Assisted Living Facilities: State Law Accommodation*, 26 BIFOCAL 1 (2004).

2. Kyle Sammin & Sally Balch Hurme, *Guardianship and Voting Rights*, 26 BIFOCAL 1, 12 (2004).

3. Doe v. Rowe, 156 F. Supp. 2d 35 (D. Me. 2001).

4. Sarah M. Sled, *Vertical Proximity Effects in the California Recall Election* 1 (Caltech/MIT Voting Tech. Project, Working Paper No. 8, 2003), http://vote.caltech.edu/media/documents/wps/vtp_wp8.pdf (on file

II. THE COGNITIVE AND TECHNICAL CHALLENGES OF ELECTION DAY

As a poll watcher, I have observed election operations in Nevada, California, Illinois, Massachusetts, and Louisiana. Watching hundreds of polling places has provided valuable feedback into the quantitative research and prompted ideas for timely solutions to endemic problems. Field observation can provide an immediate way to see which technologies are effective. Throughout this article, I will illustrate the importance of field observation by sharing numerous personal experiences. For example, during a two-day observation session with the Caltech/MIT Voting Technology Project in a 2002 Chicago congressional election, I began to witness a particular archetype of voter.[5] This archetypal voter appeared several times at the thirteen different polling sites I watched. The voter was elderly, very determined, and overly well-dressed. The voter would arrive at the site struggling to move and assisted by someone who was likely in his or her forties or fifties—probably a daughter or son. The voter would make his or her way proudly to the voting booth, with the assistance of this other person, then the elderly person would make voting selections. In one election with 109 races, an elderly voter came out of a booth after voting and put his ballot into the scanner. A poll worker verbally alerted the voter that he had under-voted on some of the races and over-voted on others.[6] The elderly voter dutifully went back into the booth and tried to correct these errors for another twenty minutes. When the elderly voter put his new ballot into the reader, he was again admonished for these "residual" votes. The person went back in. When he came out this time, there were no mistakes. How the voter had eliminated all the under-votes is an open question—possibly the elderly voter simply filled in votes for the races he was unfamiliar with. Making an informed selection for 109 different races on a single ballot may be a goal, but many times citizens may end up voting in races they do not understand.

In many polling sites, voting equipment indicates the presence of residual votes, under-votes, and over-votes only after voters have completed their ballots. This may undermine their confidence, especially in voters of age. For example, in Chicago, the PBC 2100, a piece of voting equipment manufactured by Election Systems & Software, was used to test ballots.[7] The PBC 2100 consisted of a

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with the *McGeorge Law Review*) (discussing the number of votes a particular candidate received in relation to the candidate's placement on the ballot, including punch card, optical scan, and touchscreen ballots).

5. This passage draws from visits by the author to Cook County and Chicago, Illinois, during elections in March and October of 2002.

6. An over-vote consists of marking too many candidates for a single race; an under-vote consists of not completing a selection for the race.

7. This passage is drawn in part from the author's experiences with the PBC 2100. The PBC 2100 was retired in 2005. For information about the PBC 2100, see Robert A. Wilson, *Are Chicago and Cook County Wasting $25 Million on Inferior, Non-Compliant Voting Technology?*, OPEDNEWS, Feb. 14, 2007, http://www.wheresthepaper.org/OpEdNews060214AreChicagoAndCookCtyWasting25MSequoia.htm (on file with the *McGeorge Law Review*).

special ballot box with a precinct scanner. It optically scanned a punch card to determine if a person had residual votes. If residual votes were found, the PBC 2100 allowed the voter to override the warning message, add selections to the same ballot, or "spoil" the ballot and get a replacement. Voters became confused and frustrated by this process. In fact, it was unclear whether the machines' notification of residual votes prompted voters to go back to make the selections they wanted or whether the machine simply added anxiety and an impediment to the voting experience. The machines' procedure was confusing enough that election officials had posted specially identified poll workers near the devices to explain the meaning of the liquid crystal displays and printouts. But even with that assistance, the process was still difficult for voters to understand. In many cases, voters knew that they had not voted, but they did not know what to do about it. Fewer than ten of the more than two hundred observed took the opportunity for a second chance to fill out their ballot. Perceptual and short-term memory problems added a further layer of difficulty to understanding the delayed and complex feedback.

Polling technologies can be so intimidating that an elderly voter will often bring a friend or family member to assist them. The presence of another person in the voting booth leads to the question of who is actually deciding the ballot selections. As an example, I witnessed a woman in the 2002 Chicago election who appeared to have a conflict with her daughter. I could hear the flurry clearly from the polling booth:

> The daughter said, "We like this person."
> To which the mother protested, "Well, I thought I was going to . . . ."
> "No, no, we vote this way, this is how we feel about this."

It is possible that the mother and daughter had discussed the election earlier, and the mother may have asked her daughter to remind her of her selections. But listening to the exchange, it was not clear whether the mother was making her own voting decisions at the poll. Whenever assisted voting occurs, coercion is a concern. The disabled community consistently feels uncomfortable about assistance, and many advocates call for successful independent access to voting.[8]

The hurdles to voting can often reside in the voting technology itself. Many times, new interfaces and devices create new opportunities for access and create burdens at the same time. One of the largest changes in voting technology is the rise of all-electronic voting machines, called Direct Recording Electronic devices or DREs. In 2006, DREs were the second most common voting technology, used by over thirty-nine percent of U.S. voters.[9] For the elderly, many experiences

8. *See* Andrea Senteno & Doug Israel, *Poll Site Access for the Disabled*, GOTHAM GAZETTE, Aug. 2007, www.gothamgazette.com/article/voting/20070823/17/2265 (on file with the *McGeorge Law Review*); Ray Campbell, *Why the Future of Disability Rights Depends on Our Vote*, THE CATALYST, Feb. 2004, www.ccdionline.org/newsletter.php?article_id=7& (on file with the *McGeorge Law Review*).

9. Press Release, Election Data Services, 69 Million Voters will use Optical Scan Ballots in 2006 66

with DREs have been positive. In the Reno, Nevada, September 2004 primary, I watched a very old woman—the most elderly person I had seen all day—come in to vote.[10] She arrived alone with a walker.[11] Accessible voting opportunities were available via a suite of new electronic voting machines, and she spent maybe fifteen minutes voting.[12] An overly helpful poll worker talked to her several times during the process.[13] It seemed that the elderly woman had tremendous difficulty voting.[14] As she left the polling place, I caught up with her in the parking lot and asked about her voting experience with the electronic systems.[15] She said quite articulately, "I really love the bright colors and big buttons. It makes it so easy, much better than finding the place to mark."[16] Apparently, she felt great success using the new equipment and simply took her time. The woman compared this with her past experience with optical scan ballots, she "described the screen as 'easier to read' and 'a lot easier than the type where you fill in a circle.'"[17] In a nutshell, the elderly woman from Reno, Nevada delivered the findings of various usability experiments over the last decade. First, optical scan ballots can be hard to read and follow for older people. Second, cards require care to punch and extra steps that can introduce errors into the process.

In some cases, new voting technologies experience growing pains, especially when poll workers are expected to set up and maintain new voting machines. At polling places around Boston in 2006, no one was able to use the Automark ballot marking machines for disabled people because of the machine's incorrect setup.[18] A less worrisome example came from Reno, Nevada in 2004, when voters were given unsharpened pencils to make selections on a touchscreen designed for fingers.[19] I watched an elderly gentleman spend a long time voting.[20] This voter chose to use the eraser end of the pencil to poke the liquid crystal display surface.[21] He took a long time to vote partly because he needed multiple jabs at the screen to make a selection.[22] Because of a poor polling place setup that

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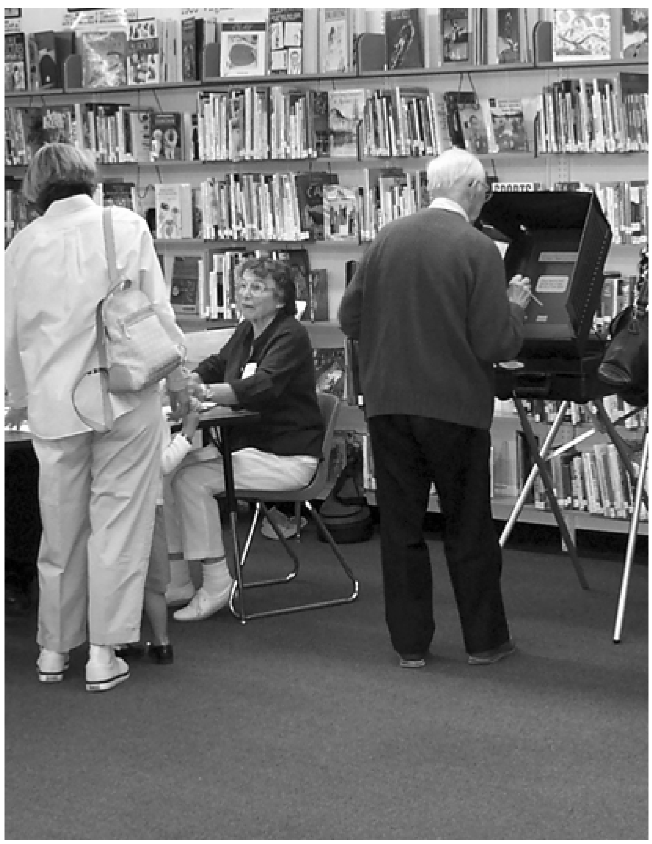
Million Voters will use Electronic Equipment (Feb. 6, 2006), http://www.electiondataservices.com/EDSInc_VEStudy2006.pdf [hereinafter Election Data Services] (on file with the *McGeorge Law Review*).

10. Ted Selker, *A Day of Poll Watching Reno and Sparks Nevada*, UX, Feb. 2005, at 7-13.
11. *Id*.
12. *Id*.
13. *Id*.
14. *Id*.
15. *Id*.
16. *Id*.
17. *Id*. at 9.
18. This passage draws from observation sessions by the author to polling sites in Arlington, Boston, and Cambridge, Massachusetts in November, 2006.
19. TED SELKER, A DAY IN THE LIFE OF AN AVID POLL WATCHER, RENO/SPARKS, NEVADA SEPTEMBER 7, 2004 6, Feb. 2005, http://context.media.mit.edu/press/wp-content/uploads/2006/07/pollwatching.pdf (on file with the *McGeorge Law Review*).
20. *Id*.
21. *Id*.
22. *Id*.

limited privacy, I was able to witness his difficulty from across the room. Because it took him so long to vote, I asked the elderly gentleman about his experience when he finally departed. In an enthusiastic tone he answered, "No problem" and "Next time will be a breeze."[23] And yet I knew better. This voter had been very frustrated when voting, and his difficulties were apparent in his body language. His patience was strained, and I am sure that the stress had an impact on his concentration. I hope that he voted the way he wanted. This example highlights the need to eliminate factors that distract voters from the task at hand. Impediments to voting for elderly people can appear in the form of unreasonable challenges to dexterity, bad instructions, and complicated polling place operations.

Figure 1: Voter, at right, using a pencil to make onscreen selections.



23. *Id.*

Other human factors can also jeopardize the voting process for elderly voters. This is especially pertinent in the context of registration and polling place check-in. In a New York experiment, the Caltech/MIT Voting Technology Project tested polling place visitors for reading disabilities.[24] While conducting the experiment, I observed many poll workers.[25] A poll worker who said she had worked in elections for fifteen years was helping me with the polling operation. Her job was to read registration names as people spoke them and mark that they were registered. However, despite so many years of being a poll worker, she could not accomplish this matching task. Although she was able to say a name when she read it or recognize a name when a person said it, she was unable to compare a spoken name to the text simultaneously. Because she had difficulty with her prescribed action, I gave her the opportunity to vote on two machines as part of our experiment. The experimental design included a reading test and a cognitive test between voting experiences. Her cognitive level was very low. This was a cause of concern because poll workers have a role in making voting technology easy to use and free of errors for voters. Poll workers must be able to set up equipment and do their jobs correctly for anyone to vote successfully.

On the route to more accessible voting technologies, this article discusses a number of simple-to-implement opportunities to improve voting for elderly people. This article describes how structuring voting with the help of electronic interfaces can help organize voters' tasks, as can redundancy, simplicity, and some kinds of electronic verification. Physical accessibility, such as height, visibility, and external noise, also plays a factor in the suitability of an electronic system. Finally, this article considers training materials for voters using new technologies—materials that are too difficult to navigate, especially for those voters with concerns about their ability to understand or learn new information.

As you read this article, consider three generic types of elderly voters as examples. First, consider the person who is frail, competent, and energetic. This voter will solve cognitively difficult problems and not be troubled by perceptually difficult problems and mechanical issues. Second, consider the person who is frail to the point of being coerced, either by a person assisting them or a complex procedural action, such as an overly long ballot and a requirement to fill out the entire ballot. This elderly voter might be able to vote correctly on his own with assistive aids, but there are several hindrances at the polling site, including election workers not understanding the elderly voter, workers confusing the elderly voter with attention or inattention, and workers and other voters coercing the elderly voter either explicitly or by assisting them in a way that influences the elderly voter's vote. And third, consider the person who

24. Ted Selker et al., *Who Does Better with a Big Interface? Improving Voting Performance of Reading for Disabled Voters* § 2.3 (Caltech/MIT Voting Tech. Project, Working Paper No. 24, 2005), http://www.vote.caltech.edu/media/documents/wps/vtp_wp24.pdf (on file with the *McGeorge Law Review*).

25. The remainder of this passage draws from the author's personal experience while conducting the reading disability experiment in New York.

is confused or may be experiencing severe cognitive disabilities. This voter might be able to make decisions with memory aids and redundant markers on a ballot or be able to succeed with audio or textual redundancy and other cognitive and perceptual aids. Unfortunately, the voter's cognitive frailties mean that the introduction of complicated instructions can reduce the ability to independently understand how to make selections. An untrained, unsophisticated human voter assistant can lead to this voter becoming disturbed emotionally, as well as confused intellectually. This voter's disabilities might also make him or her susceptible to coercion. The first two voter archetypes face difficult physical and perceptual challenges to voting; these issues can be addressed by straightforward improvements in voting interfaces and processes ranging from registration to voter check-out at the polling site. The last voter archetype—the one with cognitive challenges—will require designers of electronic voting processes to engage in deeper thinking about how processes and electronic interfaces can be improved to bring out this voter's capabilities. All the improvements we will consider for these voter archetypes are continuous with changes necessary to improve the voting performance of all voters.

III. PROBLEMS WITH TRADITIONAL VOTING APPROACHES

Technology has been improving the accuracy of voting for a long time. One historical origin for voting can be traced to Greece with the use of *ostraca*, where chips of ceramic were put into a vessel and counted. Of course, other kinds of voting—such as a black ball used to signify that one person did not like another—have also been used from very early times. In modern times, paper ballots are used for voting where a ballot is either marked on by a voter or assigned to a voter. A current example of an "assigned ballot" can be found in the Basque area of Spain, where each political party prints a ballot and a voter chooses the ballot of his party to insert into the voting machine.[26] The benefit to voters is that they only have to select a group of candidates and then insert their pre-printed selections into the voting box without having to explicitly mark an intended vote. The drawback is that there have been times in the United States when agents of one party would put a ballot into a voting machine, named as though it were from the other party.

In the 1890s, problems with ballot stuffing, bad counting, bad ballots, and coercion of other sorts led U.S. citizens to call for the elimination of paper ballots altogether.[27] As a result, lever machines were invented and gained popularity.[28] Most of the United States had moved to lever machines in the early twentieth

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26. *See* Kim Alexander, *Observations of the Basque Government's "Demotek" Voting System*, http://www.calvoter.org/news/cvfnews/cvfnews041504.html#basque (last visited Aug. 4, 2007) (on file with the *McGeorge Law Review*).

27. ROY SALTMAN, THE HISTORY AND POLITICS OF VOTING TECHNOLOGY 160 (2006).

28. *Id.* at 161.

century, but only New York still uses these machines today.[29] Lever machines provide many benefits to voters in the form of cognitive aids. For example, when a voter closes the curtain, the machines set themselves. When a voter opens the curtains, the machines attribute the specific selections to the voter who is leaving. This is a redundant memory aid for voters, reminding them that they are making final selections by leaving the voting booth. I have witnessed first-hand that with electronic voting systems, voters will sometimes deposit blank optical-scan ballots in ballot boxes or walk away from DRE machines without casting completed ballots. The levers are designed to be aligned so that a voter will see one voting option offset from the rest, which reminds the voter that a race still may need a selection. Lever machines provide an easily-visible, physical memory aide. However, the history of lever machines also shows that they can encourage voters to make selections for a few races and then quit. A study by Susan King Roth, performed at Ohio State University, showed that people tended to vote at the height at which their eyes meet the lever machines.[30] In other words, a tall voter would tend to vote for selections higher on the ballot and leave other selections untouched.[31] Roth's research showed that a high percentage of her test subjects failed to vote at all in races that were not at their immediate eye level.[32]

Election officials have long sought to apply various technology solutions to make voting systems more secure and efficient. In the early 1960s, ballot designers introduced the idea of a hole or mark in a card or ballot.[33] Some of these cards—dubbed "mark sense"—recorded voters' selections using a pencil with special electrographic lead. Once marked, the paper itself became machine readable so that the paper surface contained the ballot template and the voters' selections on the same surface. These were first used in Kern County, California in 1962.[34] Unlike a punch card, a "mark sense" ballot could not be accidentally associated with the wrong punch materials at the point of voting because users marked directly on the ballot. "Mark sense" ballots also have an ergonomic advantage over punch systems because the "mark sense" ballots use a typical pencil or marker, not a punch tool that may be difficult for users to become familiar with and use properly.[35]

The use of a typical punch card was introduced near the same time as "mark sense." Punch cards were first used for voting in Fulton and DeKalb Counties in

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29. *Id.*

30. Susan King Roth, *Disenfranchised by Design: Voting Systems and the Election Process*, 9 INFO. DESIGN J. 1, 4 (1998), http://www.informationdesign.org/downloads/doc_roth1998.pdf (on file with the *McGeorge Law Review*).

31. *See id*.

32. *Id*. at 4-5.

33. SALTMAN, *supra* note 27.

34. *Id*.

35. In the Caltech/MIT Voting Technology Project study in Cook County, Nevada 2000 punch cards, we found that pushing a selection through the template of a punch card off axis in a voting template can take several kilograms of force.

Georgia in 1964 and became more popular than "mark sense," possibly because the punch card system was easier to store and faster to scan. Punch cards are often called "Hollerith" cards, after Herman Hollerith who developed the punch card format in 1890 for the U.S. Census. One popular version of the voting format, the Votomatic pre-punched cards, do not contain actual ballot information. Instead, the card slides into a carrier ballot voting machine with a template, allowing the voter to push chads out of the ballot to form rectangular holes. The Votomatic aligned these holes with a separate card to the side that identified each race and its candidates. This type of punch card has engendered the worst residual voting rate of any voting system today. The poor residual voting rate is likely due to ballots that are difficult to interpret, alignment problems, poor pre-scoring, separation of the ballot and information, and paper handling and counting problems. Under the Help America Vote Act of 2002 (HAVA), Votomatic and all other punch cards had to be replaced by 2006.[36] If these problem-ridden systems were not replaced, funds granted under the HAVA had to be returned.[37]

Systems in which the ballot itself does not contain information about the specific races and candidates are confusing, especially to a person with cognitive or physical disabilities. This confusion can arise today in punch cards—which are still used by approximately three percent of voters in the United States[38]—and in punch card substitutes, such as the marked card, Inkavote, that is currently used in Los Angeles.[39] The separation of a ballot card from an election template means that the card has to be inserted correctly and completely into the proper voting machine. Once the ballot is taken out, it is possible to have the ballot attributed to a different template and register incorrect votes. For example, in Chicago in March 2002, I watched as poll workers accidentally issued the wrong template to voters sixty percent of the time.[40] This occurred because poll workers did not understand the importance of making the correct voting card selections. In that case, more than half of voters were unable to vote correctly for a senatorial election in a split precinct. To avoid this, voters would have had to understand issues that even poll workers had not been clear about, and voters would have had to ensure that the ballot card on their voting machine was correct and appropriate for their district.

Optical-scan systems, the leading means of voting used by approximately forty-one percent of U.S. voters,[41] are also vulnerable to errors by election

36. 42 U.S.C. § 15302(a)(2) (2006).

37. *Id.* § 15302(d).

38. Election Data Services, *supra* note 9, at 1.

39. Cal. Sec'y of St. Debra Bowen, Elections and Voter Information, http://www.sos.ca.gov/elections/voting_systems/inkavote.htm (last visited Aug. 4, 2007) (on file with the *McGeorge Law Review*) (noting that Los Angeles County uses the Inkavote).

40. *See supra* note 5.

41. Election Data Services, *supra* note 9, at 1.

officials who hand out incorrect ballots. However, this problem is much more noticeable than those caused by unlabeled punch cards. Optical-scan systems can also pose difficulties for voters with physical or cognitive challenges. The layout of optical-scan ballots often use small graphics that are difficult to see. In some cases, an optical-scan format requires that a voter complete the image of an arrow on the card. Circling it, checking it off, or drawing an "x" through any optical-scan ballot option does not make a selection. These types of marks typically invalidate the selections and are frequently invalidated when scanned by vote counting machines. Wrinkling or folding paper ballots can also affect the ballots' readability in optical-scan devices. Furthermore, dual-sided ballots potentially cause further confusion and frustration if voters forget to turn the ballots over.

Frustrations with transparency in congressional voting led Thomas Edison to patent the first electrical voting machine in 1869.[42] The first modern DRE voting machine was the Video Voter, introduced in 1975.[43] The Video Voter used a film strip to present the ballot and used "buttons and LEDs for candidate selection and display."[44] Other mixed-media machines used paper to present the selections as an overlay to buttons and lights. All such machines required voting officials to manage and align the paper and buttons. These machines are still on the market in the form of full-faced electronic voting machines that present the entire ballot to the voter at once. Modern DRE machines eliminate such mechanical problems by presenting the ballot and feedback information on an electronic display or with audio. This way, the newer voting devices have fewer opportunities for mechanical failures and present opportunities in interface design that suit elderly readers.

IV. INTERNET VOTING AND ELECTRONIC INTERFACES FOR THE ELDERLY

Several alternatives to existing voting technologies have been tested to increase voter turnout—which can be a good indicator of accessibility—voter enfranchisement, and navigability through the voting process. In the United Kingdom, researchers evaluated voting by postal mail, Internet, telephone, kiosk, and text message, and reported their findings after the 2002 elections.[45] In these

42. U.S. Patent No. 90,646 (filed June 1, 1869) (patenting the electric vote recorder). *See also* Lemelson-MIT Program, Inventor of the Week: Thomas Alva Edison, http://web.mit.edu/invent/iow/edison.html (last visited on Aug. 4, 2007) (on file with the *McGeorge Law Review*).

43. Nat'l Inst. of Standards & Tech., Pub. Hearings (Sept. 20, 2004), http://vote.nist.gov/PublicHearings/9-20-94%20Panel%203%20DEUTSCH.doc (on file with the *McGeorge Law Review*) (testimony of Herb Duetsch).

44. *Id*.

45. *Modernizing Elections: A Strategic Evaluation of the 2002 Electoral Pilot Schemes,* THE ELECTORAL COMMISSION 3 (2002), http://www.electoralcommission.org.uk/files/dms/Modernising_elections_6574-6170__E__N__S__W__.pdf (on file with the *McGeorge Law Review*). Voting by "kiosk" involved voting at a specific terminal. *Id*.

elections, the average voter turnout rate was 32.8 percent;[46] however, a two to twelve percent difference in turnout was observed when Internet voting was made available.[47] The U.K. Electoral Commission noted that Internet voting allowed disabled persons to participate from a larger number of locations, specifically, "anywhere there was a computer connected to the web."[48] Although the U.K. Electoral Commission found that the Internet still posed some barriers to disabled persons, the Commission noted that further testing could remove those barriers.[49] The issues of mobility, the complexities of navigating through polling site check-in, and voting itself are at least as difficult for elderly people as for anyone else. Many elderly and non-elderly voters would likely take advantage of well-designed Internet alternatives to on-site voting.

Internet voting is currently not used in the United States but was used with favorable results in the 2000 Arizona Democratic presidential preference.[50] Security was maintained during the Internet voting election with various means of protection, including ballot validation, data encryption, voter identification, intrusion protection, and audit trails.[51] Today, the discussion of voting technology has focused on the dangers of hacking and software security breaches.[52] Non-government Internet voting is currently practiced in the United States by companies, such as eGov, which run corporate and shareholder elections for various private clients.[53] "Internet voting" entails making selections on a website or other interface via a networked computer, then having selections counted electronically on a server or the voter's client computer. A different sort of Internet voting was tried in 2000 with the FVAP Internet Voting Project, the Department of Defense's effort to get ballots to overseas voters.[54] In the test, voters living abroad were asked to go to a specific test terminal, log in with two different passwords, and pull up the ballot for their home voting precinct in the United States. The voter would print out the ballot image and fill it out in pencil. An image of the ballot page would be then transmitted either by fax, mail, or

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46. *Id.* at 61.

47. *Id.* at 46.

48. *Id.* at 64.

49. *Id.*

50. ROBERT S. DONE, THE PRICEWATERHOUSECOOPERS ENDOWMENT FOR THE BUS. OF GOV'T, INTERNET VOTING: BRINGING ELECTIONS TO THE DESKTOP 6, Feb. 2002, http://www.businessofgovernment.org/pdfs/Done_Report.pdf (on file with the *McGeorge Law Review*).

51. *Id.* at 8.

52. *See, e.g.*, LAWRENCE NORDEN, BRENNAN CENTER FOR JUSTICE VOTING TECHNOLOGY ASSESSMENT PROJECT, THE MACHINERY OF DEMOCRACY: VOTING SYSTEM SECURITY, ACCESSIBILITY, USABILITY, AND COST 17-27 (2006), http://www.brennancenter.org/dynamic/subpages/download_file_38150.pdf (on file with the *McGeorge Law Review*).

53. *See* eGov Consulting, http://www.egovconsult.com (last visited Aug. 4, 2007) (on file with the *McGeorge Law Review*).

54. DEP'T OF DEF. WASH. HEADQUARTERS SERVS. FED. VOTING ASSISTANCE PROGRAM, VOTING OVER THE INTERNET PILOT PROJECT ASSESSMENT REPORT (June 2001), www.fvap.gov/services/voireport.pdf (on file with the *McGeorge Law Review*); Todd J. Gillman, *The Military Will Test Presidential Voting via the Internet*, DALLAS MORNING NEWS, Jan. 4, 2000.

Internet back to the voter's precinct. Election officials would then count the ballot by hand or by optical scan just as they do with other absentee ballots. The demonstration netted only eighty-four votes from overseas service people, but this simplified form of Internet voting may be superior to networked transmission of voter selections in terms of security risk. In any case, both types of Internet voting could provide clues to those designing election technologies for the elderly. Many times, the ability to get to the polling place is the only hindrance to voter turnout from the elderly populations.

As the use of computers for people with dementia and other cognitive disabilities is discussed, a question arises whether memory loss and dementia necessarily make it harder to use computer interfaces. Consider the following information regarding The Learning Center, an interactive experience for Alzheimer's victims created by an MIT research project.[55] The Learning Center is not an Internet voting system, but an activity center that studies whether people with Alzheimer's could successfully navigate online.[56] Researchers identified a number of cognitively simple and difficult tasks and attempted to create an environment that would engage an Alzheimer's patient. In beta tests of the site, Alzheimer's patients were able to move the cursor or arrow keys to make selections. However, when Alzheimer's patients were doing that task, they were absorbed in pressing the keys as opposed to the task of running the interface. To avoid this distraction during the tests, researchers found that giving the caregiver the controls and asking the Alzheimer's patient to direct the interface increased the productive interchange between them.

In building the interface, researchers attempted to learn what kinds of activities were easy for Alzheimer's patients to use. The simple answer was that anything distracting or confronting could lead to anxiety. The best strategy was to organize all the information required to make decisions in a concrete visible form in one central area. Distractions such as email, instant messages, and family photos were eliminated because they would require memory tasks. Instead, the interface employed generic images and generic interactions—such as looking through image catalogs which would allow our subjects to perceptually make decisions. Applying this research to voting, effective election systems should allow a voter to navigate via pictures and text without excessive demands on memory, allowing voters to make decisions on the spot. Interfaces developed to focus attention on the specific task at hand will be more successful with Alzheimer's populations than ones in which voters are taxed to remember various navigation and procedural steps. For persons with cognitive challenges, the time allotted to various tasks is crucial. In the research with the Living Center, the interface itself leads the user through the activity. When I created an

55. This passage draws from the author's personal experience working with the research team who constructed The Learning Center.

56. PBS, The Forgetting-The Living Center, www.pbs.org/theforgetting/livingcenter (last visited Aug. 4, 2007) (on file with the *McGeorge Law Review*).

interactive puzzle game for patients, a graphic of a puzzle piece moved on the screen among the graphical choices to prompt the patient to make a decision, instead of waiting for a patient to take actions. In the sphere of voting, one could imagine an electronic ballot interface that would literally point at different selections to suggest to voters that a selection needed to be made. Another aid to helping patients master computer interfaces was the use of large, easily identifiable objects on the screen. The Living Center project features an easily identifiable fireplace, pictures on the wall, and a window. This interface made it easier for people to make selections regardless of whether they recognized the pictures. In fact, in our experiments, small bears leaning up against a car were interpreted as cute, curious, and elicited delight in patients. These might not seem like important issues, but a number of subtle features in an interactive environment can improve the confidence and performance of Alzheimer's patients using computer systems.

V. DRE Accessibility for Those with Cognitive Disabilities

DRE voting machines, currently the second most widespread means of voting in the United States, have the potential to greatly improve voting for those with physical and cognitive disabilities. But currently, fully electronic devices carry some of the same impediments as their analog and optical-scan counterparts. Two of these impediments arise from full-faced ballots and designs that aggravate problems for those with reading difficulties. Full-faced ballots are ones in which all selections for all races are crammed onto a single ballot, whether electronic or mechanical. In my tests with several different voting systems, it appeared that all the full-faced systems were easier to navigate; however, experience dictated that full-faced ballots tended to be under-voted.[57] I looked at ballots on voting machines, such as Election System & Software's (ES&S) iVotronic, which has a page-by-page interface, as well as ES&S's full-faced V2000 and a prototype full-faced ES&S device with a large liquid crystal display showing all ballot names and races at the same time.[58] The result was that voters tended to miss more selections on full-faced formats than they did on direct record electronic voting machines that went page-by-page. It is possible that interface improvements might allow the enlargement of the viewable area to aid voter orientation, but this has not yet been researched.

I also discovered that voter reading disabilities gravely exacerbated error rates in full-faced ballots. In my experiments in New York, I tested voters for reading disabilities.[59] Fifteen percent of the population has a reading disability;

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57. *See* Selker et al., *supra* note 24, at 8 ("For all subjects, page-by-page DRE systems significantly reduce under-votes, while increasing the total time to complete the ballot.").

58. *Id.* at 12.

59. Jonathan A. Goler & Edwin J. Selker, *Comparative Voting Performance of Reading Disabled Voters* (Caltech/MIT Voting Tech. Project, Working Paper, 2005), http://www.vote.caltech.edu/media/documents/

eighty-five percent of those individuals have dyslexia.[60] In the context of voting, I found a large difference in error rates between voters diagnosed with reading disabilities and those without. The error rates on DRE machines were extensive. Even when the page layout visually prompted voters to move from one selection to the next, voters would under-vote, either by not selecting anything on that page or by selecting fewer options than they should in some other way. Frequently, researchers can diagnose ballot design problems through staged experiments. Another good method for discovering interface problems is to compare the performances of similar ballot presentations in live elections. In DeSoto County, Florida, in the 2006 Congressional Thirteenth District, a relatively low one percent of voters under-voted.[61] In nearby Sarasota County, thirteen percent of voters under-voted when a race appeared at the top of a page in very small print and a larger print race appeared below it.[62] In nearby Charlotte County, twenty-two percent of voters missed voting on the attorney general's race when it was similarly orphaned as a small race the bottom of the page.[63] I believe that poor ballot design drove these problems.

The large error rates from users of full-faced voting systems speaks to the need for further work in clearly identifying selections with very large, simple graphics. I have discovered that these can be more important in populations of age. Since 2001, the lab at MIT has looked for solutions to common ballot interface problems with a ballot design called LEVI (the Low-Error Voter Interface) developed as a benchmark.[64] I continue to experiment with and refine the visual features of the LEVI interface to improve tested results. The LEVI interface shows one race per screen. A set of tabs on the left side of the screen represents every race available for voting. These races are easily accessed but only viewable when selected. Such an interface orients the voter performing the task by giving them a visual focus. For a person with perceptual or cognitive difficulties, this orientation is even more crucial. The tabs to the left in the LEVI interface visually reflect whether or not a race has been completed. If a selection for congressional representative is made, for example, the tab color will change from gray to textured green as you see in the following image. In this case, voters

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readingdisabledwist.doc (on file with the *McGeorge Law Review*).

60. LD Online, Dyslexia Basics, http://www.ldonline.org/article/16282 (last visited Aug. 4, 2007) (on file with the *McGeorge Law Review*).

61. Bob Mahlburg & Maurice Tamman, *Recount: Dist. 13 Voting Analysis Shows Broad Problem*, HERALD-TRIB., Nov. 9, 2006, at A1, http://www.heraldtribune.com/apps/pbcs.dll/article?AID=/20061109/NEWS/611090343 (on file with the *McGeorge Law Review*).

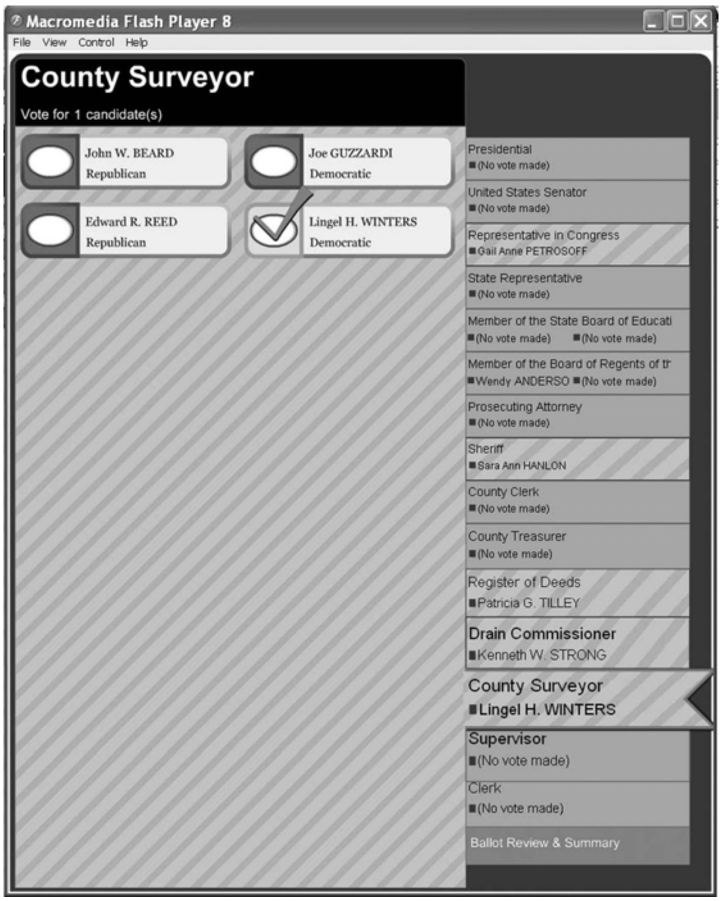
62. Jim Stratton, Mark Matthews & Roger Roy, *Florida Voting Machines Show High Number of Blank Ballots*, ORLANDO SENTINEL, Nov. 9, 2006, at C2.

63. *Id.* (ballot design observations based on the author's first-hand review of ballots).

64. Ted Selker et al., *Orienting Graphical User Interfaces Reduces Errors: The Low Error Voting Interface* § 3.3 (Caltech/MIT Voting Tech. Project, Working Paper No. 23, 2005), http://vote.caltech.edu/media/documents/wps/vtp_wp23.pdf (on file with the *McGeorge Law Review*).

can always double-check that they completed the race for "Representative in Congress" even as they are voting for other races.

Figure 2: The experimental LEVI voting interface, created with Macromedia Flash software.



LEVI has demonstrated that redundant information in the tabs can reduce the rate of overlooking mistakes in selections even for able-bodied voters. In our study, the average number of errors for the LEVI system was 1.8 versus 3.1 for a typical direct record electronic interface.[65] I have worked with tab styles that would allow me to show full text for each of the races, albeit in a form that is greatly reduced in size. The races closest in sequence to where the voter is currently working are rendered in the highest resolution, while the races earlier or later on the ballot are shrunk down so that the screens only show the name of the race and whether it has been completed. Using this so-called "fish-eye"

65. *Id.* at 11.

approach, a voter can select a race by its tab to find out more information about it, even before he selects its full-page selection pane. By moving down through the ballot, the interface is constantly reminding voters of the nature of races and their completion status.

Many times, with traditional voting systems, a lack of good labeling on the ballot can disorient voters. For example, in a 2006 race in the Boston area, only the candidate's last name appeared on the optical-scan ballots.[66] Voters who were concrete thinkers might have expected the full name to be on the ballot and may have neglected to vote for the race. The redundant information of the LEVI interface—tabs, bold color-shifts, and dynamic labels—gives voters more opportunities to discover their mistakes.

Figure 3: Voter instructions on a Reno, Nevada voting machine.

In some cases, an interface's job is to help the voter make a race selection; other times, its purpose is to instruct voters on its use. In Nevada, a DRE voting machine bore the image shown above, offering clear instructions on the necessary steps required to vote. Many times throughout the day, I watched people religiously go through these four steps (touch, change, continue, review) by putting their fingers on the screen and following down. Using a finger as a cognitive prosthetic is common for many people, regardless of whether they are suffering from short-term memory loss. Any set of "best practices" for voting systems should mandate that electronic voting interfaces provide ways to visually

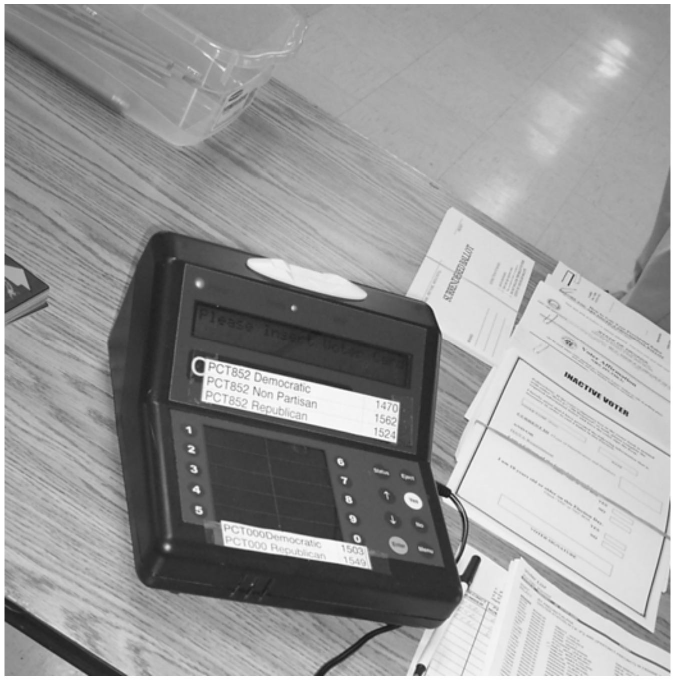
66. This passage draws from observation sessions by the author to polling sites in Arlington, Boston, and Cambridge, Massachusetts in November 2006.

isolate the steps as voters are reading them. Voters should also be able to refer back to instructions as they are using voting machines.

Optical-scan ballots do not provide a way to manipulate the interface to change the point of focus for the voter. All the races are presented sequentially on a single page. However, people with reading or cognitive disabilities use known coping mechanisms for tackling the task of voting. Putting a ruler across the text and reading it audibly can reduce the number of errors tremendously. My research group has started giving election officials long, straight magnifying glasses. The distribution of magnifying glasses will hopefully encourage election officials to provide voters with these glasses and to consider sourcing magnifying glasses in future elections. Long, straight magnifying glasses can help voters orient themselves along a magnified strip across the page. I believe this might also help voters as a physical memory aid, like folding towels—a skill often enjoyed by people suffering from Alzheimer's. The towel in hand leads a person from one fold to the next, making it easier to continue the action. A magnified ruler, and the act of going down the page, can prompt a voter to continue the task sequentially and to lock onto the selection accompanying its textual description.

DRE machines obviate some of the problems of earlier election mechanisms, such as inserting a punch card into the wrong template to initiate voting. But DRE machines can also assign the wrong electronic ballots to voters. In some site configurations, poll workers use a device called a ballot creation module when checking in voters at the polling place. Voting officials assign voters an electronic ballot, often on a "smart card." An incorrect digital ballot will limit voters from entering choices for certain elections or even certain parties. In the photograph below, voters in Nevada sit frustrated because a worker inadvertently gave them a provisional-voting ballot "smart card" for a Sequoia DRE voting system. Once voters put the card into the voting machine, they were unable to vote for anything but federal elections. In this Nevada instance, the accident occurred when a voting official did not realize that provisional numbers for the ballots were different from the local precinct numbers.

Figure 4: A ballot module programmer has the potential to create the wrong ballots.



From my field observations, I know that voting site problems frustrate all voters. But for elderly voters, the problems of human error, ambiguities, and technical glitches can compound difficulties.

VI. Alternatives in Verifying Votes

Beyond simply making a selection, there is an increasingly controversial step in the voting process. This step involves helping voters double-check their own selections on ballots. The HAVA mandates that a voter have a second chance to verify his vote and change it. This can be accomplished though an electronic review pane on a DRE. For a cognitively energetic or active voter, the panes simply require you to remember and check your selections against those you thought were made. Typically, voters are able to find and fix errors with a review pane. Recently, election officials have introduced an additional method for verification called the Voter Verifiable Paper Audit Trail (VVPAT). Unfortunately, even for able-bodied people, VVPATs pose three main difficulties to finding errors. First, VVPATs present a difficult cognitive task because the paper trail is shown in a different place—a printer off to one side of the voting machine. Second, VVPATs are in a different format than the original ballot. And third, VVPATs requires that voters remember and reintroduce the information that they have already transcribed. Because the number of races in a typical American election often exceeds 500 different possibilities, the problems with recalling previously entered voting choices are significant. News reports have recently discussed government officials calling for electronic voting machine paper trails.[67] However, in my research, I have discovered that paper trails do not reliably inform voters of mistakes and have the potential to cause confusion and disenfranchisement.[68]

An alternative to the VVPAT is the Voter Audit Audio Trail (VAAT), which produces spoken feedback for ballot selections.[69] Interfaces using VAAT have been studied in the Caltech/MIT Voting Technology Project, as well as by voting machine manufactures, such as Hart InterCivic, who has demonstrated prototype devices with audio audit trails. The coincidence of a selection with audio feedback requires fewer cognitive resources for voters to catch errors or discrepancies. It is an especially helpful method for reducing the memory requirements and matching requirements for a voter with memory or cognitive disabilities.

In an Arlington, Massachusetts-based study, I tested audio verification against four different mechanisms.[70] In Group One, voters double-checked their work by examining their optical-scan ballots in an optical-scan verification machine.[71] In Group Two, voters examined a printed paper trail after using a DRE voting machine.[72] In Group Three, voters examined a paper trail showing one race at a time as they voted on a DRE voting machine.[73] And in Group Four, voters listened to a simultaneous audio track stating what race they were currently voting in and for whom who they were voting.[74] These experiments yielded simple results. Voters uniformly ignored errors identified on the optical-scan verification and were not good at finding errors in the paper trail from the DRE.[75] Many likely considered their voting session completed and were

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67. Ian Urbina & Christopher Drew, *Big Shift Seen in Voting Methods With Turn Back to a Paper Trail*, N.Y. TIMES, Dec. 8, 2006, at A1.

68. Ted Selker & Jon Goler, *Security Vulnerabilities and Problems with VVPT* 6, 8 (Caltech/MIT Voting Tech. Project, Working Paper No. 13, 2004), http://www.vote.caltech.edu/media/documents/vtp_ wp13.pdf (on file with the *McGeorge Law Review*).

69. Ted Selker, *Fixing the Vote*, SCI. AM., Sept. 17, 2004, http://www.sciam.com/article.cfm?chanID =sa006&colID=1&articleID=00018DD5-73E7-1151-B57F83414B7F0000 (on file with the *McGeorge Law Review*).

70. Ted Selker et al., *A Methodology for Testing Voting Systems*, 2 J. USABILITY STUD. 7, 11 (2006), http://www.usabilityprofessionals.org/upa_publications/jus/2006_november/selker_rozenwieg_pandolfo_testing _voting_systems.pdf (on file with the *McGeorge Law Review*).

71. *Id.*

72. *Id.*

73. *Id.*

74. *Id.*

75. *Id.* at 13.

unwilling to spoil their ballots and take new ones. In the group with contemporaneously printed paper trails, voters caught and corrected sizably more errors than with paper trails printed at the end of the session.[76] The paper trail provided a perceptual task associated with the task of voting at the time of the race, and voters frequently consulted it to double-check their work. This system, however, extended the time required for voters to complete ballots.[77] Finally, voters caught the most errors when audio ballots announced selections as they were made, prompting voters to remedy errors as they occurred.[78] I believe that an audio audit trail worked best because the trail provided redundant information in a different sensory modality, reinforcing the task via two different cognitive inputs. Voters found the audio "interruption" frustrating but heeded the interruptions and improved their votes.[79] There are further refinements I would like to make on this experiment. My methods improved performance despite the presence of an artificial computer voice and a delay caused by prototype software. As the audio verification system is tested with natural speech and without a delay, I believe that even greater levels of error identification will be observed.

Subsequent experiments have been completed to combine some of my discrete findings. For example, by adding audio verification to LEVI in my experiments, I found that users made half as many errors on LEVI ballots compared to other ballots.[80] What is promising about these results is that none of the test subjects had special cognitive or physical needs. I plan to conduct further research to demonstrate that these effects would be even greater for populations with specific difficulties with perceptual and cognitive tasks.

VII. ENVIRONMENTAL AND INDUSTRIAL DESIGN BARRIERS TO VOTING

While improving voter access will involve making changes to electronic interfaces, environmental factors at the polling site can also add to distraction. Environmental issues become technological concerns when they involve ballot design, lighting on certain electronic interfaces, and issues as simple and critical as electrical power needs for machines.

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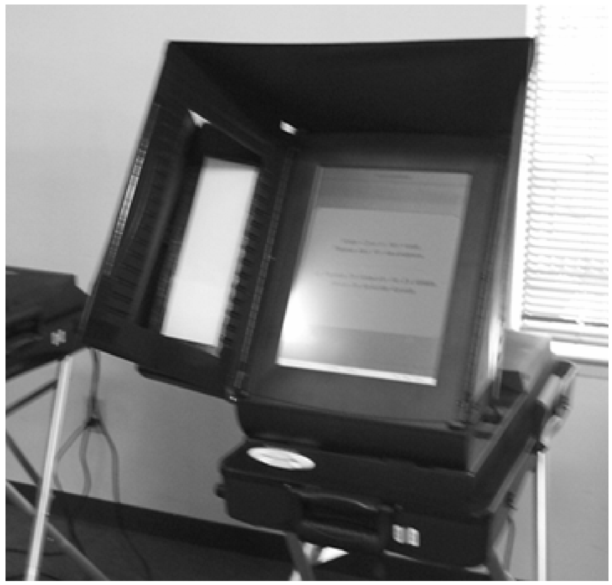
76. *Id.*
77. *Id.*
78. *Id.*
79. *Id.* at 14.
80. Sharon B. Cohen, Auditing Technology for Electronic Voting Machines 24 (May 19, 2005) (unpublished B.S. and M. thesis, Massachusetts Institute of Technology) (on file with the *McGeorge Law Review*).

Figure 5: A voting machine in Reno/Sparks, Nevada displaying a low-battery message in window.



The voting machine pictured in Figure 5 has two problems: the voting machine sits in front of a window of this Reno, Nevada site and was never plugged in by poll workers. At 7:00 a.m., I took a picture of the low-battery warning. In this case, the screen contrast was low partly because of the ambient glare from the window, which made it difficult to see the warning messages on the screen. At 10:30 a.m., the entire voting site temporarily closed because all of the site's machines had run out of battery reserves and had quietly powered themselves down.

A number of "best practices" could have been implemented to avoid the above scenario. First, the screen contrast should be enhanced overall. Second, the interface should use bolder color and imagery to convey battery warnings. And third, the voting machine should be positioned away from a window to maximize contrast. An example of a technology platform that remedied some of these issues automatically was a prototype of the Infinity Voting terminal Microvote. The Microvote had a light sensor to change the contrast of the screen when it was in dark or bright places. The Microvote was never implemented in the field, but it provides a good model for future device design. Furthermore, a downside to low-contrast screens is that elderly voters need assistance with these screens, which in turn increases the possibility of voter coercion.

Figure 6: Glare impedes voting in a Reno, Nevada site.

Another environmental factor that may lead to voting difficulties includes the availability of voter training media at polling sites. Especially for people with short-term memory problems, there is a high value to becoming comfortable with a new task or technology procedure before it is performed. With new and novel voting technologies, it is crucial that teaching aids are delivered in a systematic way, whether they are delivered through voting machine instructions, videos, or paper handouts. In Chicago, election officials made a well-produced videotape available in order to teach people how to use the new scanning paper trail system in the Election Systems & Software PBC 2100.[81] During my observation on election day, however, no one watched these videos. In some precincts, video monitors sat behind the registrar. In others, the video monitors were placed off to the side or by themselves. The video images were never located where a line would form, where voters could watch while waiting for an open voting booth. "Best practices" should be assembled to allow people to learn how to vote and to bring instructional materials into a polling place. A demonstration voting machine for voters to practice on before they enter a voting station would also be beneficial. Sample ballots and machines have long been recognized as "best practices," and yet they are often missing from sites or ineffectively presented. Two issues still remain: to the extent that training materials are available, how might voters be made aware of them, and if a sample ballot is pasted behind a registrar's desk, how might someone view the ballot.

81. This passage draws from the author's visit to Illinois in March 2002.

An increasingly important environmental factor at polling sites is overall design and architecture. Voting has always been conducted in a variety of conditions, from dark high school gymnasiums to bright post offices. But with the introduction of new DRE machines and the modernizing of equipment, design is an increasingly important factor for issues of ergonomics, visibility, and privacy. Sites with electronic systems may now have a clean, paper-free appearance, but what is often forgotten is that many voters, especially those with cognitive challenges, bring election materials with them for their personal reference. The majority of new voting booth designs and electronic voting stations do not provide a simple space to put down a piece of paper. Privacy is also an issue with the new devices. Most electronic voting stations dispense with the traditional voting booth curtain that can be pulled to ensure privacy. The anxiousness of people with short-term memory problems and cognitive and physical disabilities can be very real around this issue, and can distract them from the task at hand.

Figure 7: Improvised lamps in Roxbury, Massachusetts.

Lighting has always presented potential problems for readability at polling sites with paper ballots. This is a critical design issue that election officials should tackle as part of a checklist of "best practices" well before Election Day. Many times, poll workers on site must do their best to remedy a lighting issue, and they often have the best intentions. Figure 7 shows a photograph of poll workers in Roxbury, Massachusetts who have taken it upon themselves to hang lamps over each of the voting booths.[82] The booths were so dark that voters were

82. This passage draws from observation sessions by the author to polling sites in Arlington, Boston, and Cambridge, Massachusetts in November 2006. For a discussion of other ergonomic problems at voting sites, see Ted Selker, *The Real Problem with Voting*, TECH. REV., Nov. 2004, http://www.technologyreview.

unable to read their optical-scan ballots as they filled them out. Delays ensued at the site because voters had trouble reading and completing their ballots. And yet even after the lights were installed, many voters noted that they were still having trouble seeing. Other procedures should be in place to augment visibility. Where optical scan ballots are used, poll workers are supposed to provide magnifying glasses for voters to use. These instruments are varied in quality, and poll workers often forget to offer them. I even witnessed a poll worker taking the glasses off her head to give to a voter. While this is a kind and intimate gesture, improvisation can often hamper election site operation, and—as in the example of the improvised lighting in Roxbury—the best solution would be a set of uniform procedures for addressing visibility issues.

VIII. Accessibility Technologies Evolve

Many of today's voting machines include accessibility features exclusively for those with physical and mental disabilities. An important goal is to create and use technologies that will give access to a target audience and help others as well. Some technologies allow visually impaired people to vote by listening to recorded instructions and making selections either with audio responses or manual actions. Rhode Island uses an innovative tactile ballot, where an audio tape reads instructions and tells a voter what a mark in a specific hole is for.[83] Such a system might be more complex than a familiar keypad. Telephone audio response systems allow people to vote from anywhere, and these have been tested several places. DREs typically include the option of audio voting, which I have also found to be useful as a redundant feedback to reduce errors and create a verifiable record of selections. These audio-response systems are exciting for people with sight problems, but, to date, they have extended the amount of time it takes to vote compared with approaches for the sighted. In order to give voters every chance to succeed with accessibility technology, these technologies must be as expedient and simple as others. I am currently conducting research to reduce the amount of time it takes to vote with audio interfaces.[84] Instead of using a beep between selections, the interface utters a quickly spoken word, which helps the user perform the task with redundant information. I have found that words such as "forward," "reverse," "selected," and "unselected" can effectively orient the user and provide a prompt for the voter to act. Other techniques to improve audio voting are being tested as well. Experiments showed that a computer mouse was a superior interface for navigating through an audio

com/Infotech/13911 (on file with the *McGeorge Law Review*).

83. Office of the R.I. Sec'y of State, Tactile Ballots Used in Rhode Island (2005) http://www.sec.state.ri.us/elections/spanishmove/short%20description%20of%20a%20tactile%20ballot.pdf (on file with the *McGeorge Law Review*).

84. Reesa Phillips, Reducing the Time Bottleneck in Auditory Interfaces: Recognition and User Comprehension in Audio Content (Feb. 15, 2007) (unpublished manuscript) (on file with the *McGeorge Law Review*).

interface.[85] I imagine a day when a voter does not have to listen to repeated selections to remember where they are on a ballot.

With hearing-impaired people, I have experimented with visible prompts or vibration as feedback, and especially as redundant verification that a vote has been selected. In a proposed experiment, test subjects would sense vibrations on their hands from the voting-machine audio. Voters would potentially feel the difference between selections such as *Schwarzenegger* versus *Schwartz*: the first name is longer, with more syllables. Alternately, an audio verification system might employ a speech-to-text interpretation for hearing-impaired voters, so they could verify that their selections were made through a separate interface. Some modern voting systems also give paralyzed voters access through sip-and-puff or mouth-stick selecting methods.

The most exciting voting technology questions in discussion today involve how to make interfaces accessible so that people do not require assistance. For equipment designers and voting officials, the high road will be to allow people with cognitive and physical disabilities to vote on their own, to form their own interpretations, and to make their own selections. Many voting challenges can be addressed by better interface design: good viewability, redundancy of cues, clear and simple onscreen training materials, and the reduced cognitive complexity of onscreen environments. With more simple interfaces and fewer buttons, voters have less to learn and tend to make fewer mistakes. Many environmental deficiencies can also be addressed by technology—proper lighting and better mechanical design should be part of a standard election environment. It is still not clear how to make "best practices" simplified and standardized so that U.S. polling sites do not add extra barriers to citizens trying to vote. There is much testing to be done. New interfaces and systems have not been tested with people with cognitive difficulties extensively enough. I believe that the LEVI interface is a step toward making interfaces that reduce perceptual difficulties, difficult motor tasks, and memory burdens in making selections. My goal for elderly voters is to remove obstacles to learning about voting issues, keeping registration updated, making selections, and having their intentions recognized and respected without intervention or coercion. I am sure that this can be done in a way that improves voting for all voters. The results of my research are promising and suggest that not only can this be accomplished, it can be accomplished in a way that addresses the particular needs of voters with cognitive or physical impairments, and improves the voting experience for all voters.

85. Matthew Hockenberry et al., Abbrevicons: Efficient Feedback for Audio Interfaces 1079, 1081 (Sept. 12-16, 2005) (unpublished manuscript) (on file with the *McGeorge Law Review*).