Scantegrity Mock Election at Takoma Park

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Abstract: We report on our experiences and lessons learned using Scantegrity II in a mock election held April 11, 2009, in Takoma Park, Maryland (USA). Ninety-five members of the community participated in our test of this voting system proposed for the November 2009 municipal election. Results helped improve the system for the November binding election.

1 Introduction

On April 11, 2009, ninety-five voters cast ballots on the Scantegrity II voting system during a mock election held at the Community Center in Takoma Park, Maryland, coinciding with Takoma Park's celebration of Arbor Day. The purpose of this exercise, which we call Mock1, was to demonstrate and tune Scantegrity's capability in preparation for the Takoma Park municipal election in November 2009 [Car10]. The November election was historic — the first time any end-to-end (E2E) cryptographic voting system with ballot privacy has been used in a binding governmental election. This paper, a short summary of which appears as [She09], describes our experiences using Scantegrity in Mock1 and presents and interprets data collected through questionnaires, unobtrusive observations, and independently-administered focus groups.

Scantegrity [Cha09] is a software-independent cryptographic audit system that overlays a traditional optical-scan voting process. Voters mark paper ballots with revealing ink, exposing a randomly chosen confirmation code in each marked oval, which the voter may choose to write down on a detachable ballot chit. After polls close, each voter has the option of checking her confirmation codes online, to verify that her vote has been recorded as intended. Furthermore, Scantegrity is universally verifiable: using special software of his or her choice, anyone can verify online that the tally was computed correctly from the official data (and during the actual election, two auditors even wrote their own software for this purpose and made it public).

There has been some debate within the voting systems' community about how easily cryptographic end-to-end systems could be understood, used, and administered, but there is little evidence from which to draw any conclusions.

Mock1 is part of a larger research project to measure how easy Scantegrity is for voters to use and poll workers to administer. The research also studies how well voters and poll workers accept this revolutionary system. Mock1 only tested the Scantegrity voting system and was required to mimic a binding election. We closely followed procedures that were later used in November's binding election. These requirements constrained research methodologies, but were needed to assess viability of Scantegrity in the binding election. We plan to carry out a second mock election, Mock2, and expert review, which will be a field test comparing Scantegrity with a commercial optical scan voting system.

Our hypothesis is: Voters and election officials will accept and have confidence in Scantegrity as a viable practical high-integrity voting system. They will find it reasonably easy to use and administer, compared with traditional optical scan voting. A statistically significant number of voters will verify their votes online, and a statistically significant number of them will detect errors, if present, to produce high assurance in the election outcome.

At Mock1 we measured Scantegrity's performance through surveys, observations, and focus groups. Eighty voters and all six Takoma Park poll workers filled out questionnaires about their experiences with Scantegrity, including questions about how easy the system was to use and administer and how well they understood and accepted the system. Two unobtrusive observers watched and timed fifty-three of the voters as they voted. A professional moderator led two focus groups: one for all six poll workers and one attended by four voters. After polls closed, twenty-nine of the voters (31%) verified their votes online, using a privacy-preserving receipt on which each voter copied confirmation codes exposed during the voting process for their ballot choices.

In the rest of this paper, we briefly review selected previous work, explain our election and research methods, present and discuss our results, state recommendations, and explain our conclusions. The Scantegrity website [Scan] lists additional details about Mock1, including questionnaires and the agreement with the City of Takoma Park.

2 Previous Work

There have been several usability studies on voting systems and vote-verification systems, but no major usability study has been conducted on any E2E voting system. The only previous usability studies on E2E systems have been the preliminary studies mentioned above and a few student projects at UMBC (on Punchscan), MIT (on ThreeBallot), and Univ. of Surrey, England (on Prêt à Voter). Scantegrity and its predecessor Punchscan [Punch] were exercised by running student elections, organizational elections, mock elections, the 2007 VoComp International Voting System Design Competition [Voc07], and surveys [Scan]. Scantegrity has been used at the following events: Mock Presidential Elections at MIT and George Washington

University (November 4, 2008, Cambridge, MA, and Washington, DC); Mock Board of Directors Election for the Ottawa Canadian Linux Users Group (April 1, 2008, Ottawa, Canada); and a survey at the Claim Democracy Conference (November, 2007, Washington, DC). Essex *et al.* [Ess07] document their use of Punchscan in the 2007 student elections at the University of Ottawa.

RIES [OSCE07, Hub05] was used twice in 2004 in the Netherlands in a government Internet election. This system is voter verifiable and universally verifiable, but allows voters to prove how they voted. Helios [Adi09] was used in March 2009 to elect the President of the Université catholique de Louvain using remote voting. This system neither protected against undue influence nor compromise of the voter's computer. Byrne *et al.* [Byr07] experimentally compared the usability of punch cards, lever machines, and paper ballots; they found that voters made fewer errors with paper ballots.

Using expert review, laboratory studies, and a field experiment with 1540 participants, Herrnson *et al.* [Her08, Bed03, Con09, Her06] found that voting system interface and ballot styles had an impact on voter satisfaction, the need for help, and voters' abilities to cast their ballots as intended. They also demonstrated that the most frequent error made by voters was voting for a candidate other than the one they intended to support, usually a candidate listed on the ballot immediately before or after the intended candidate. This type of error is more serious than the errors associated with the residual vote because, in addition to denying an intended candidate a vote, it gives a vote to a candidate's opponent. They found that results of this experiment varied by voter demographics and voting experience. They also found that design issues and voter backgrounds influenced not only the voters' evaluations of different voting systems, but also their voting accuracy. Laskowski [Las04] offers practical metrics for voting system usability, and draft voluntary guidelines [EAC07] address usability.

There is a large body of knowledge about the usability of both computer systems [Shn05] and security [Cra05], but none of this work addresses how well and easily voters and election officials will be able to use Scantegrity.

Alvarez *et al.* [Alv08] and Newkirk [New08] frame public opinion about voting technologies. Newkirk finds that public opinion about voting systems has remained remarkably stable between 2004 and 2008. Direct Recording Electronic (DRE) systems were the top-rated systems in terms of voter trust throughout most of this period, followed closely by precinct count optical scan (pcos) systems. Fewer voters trusted vote-by-mail, central count optical scan systems, and Internet voting. There were some variations by background characteristics, but the overall stability in levels of trust and the near parity of DRE and pcos systems are remarkable given questions raised about these systems by serious scholars, political activists, and conspiracy theorists on the blogosphere. Indeed, public confidence in election count accuracy was ranked only second to public trust in banks and financial institutions. More confidence was voiced for elections than medical providers (including hospitals and clinics), universities and schools, large corporations, and the government.

Given the impact of public opinion on the decisions of policymakers who purchase voting systems and oversee other matters related to the administration of elections, it is important to study public reactions to voting systems. The fact that no such study has been conducted on any E2E system to date is a significant shortcoming. The Mock1 test of Scantegrity is a first step in addressing this shortcoming.

3 Methods

We now describe the voting and research procedures used in Mock1. Our research protocols and questionnaires were approved by UMBC's Institutional Review Board, as required for experiments with human subjects. Polls were open from 10 AM to 2 PM

3.1 Voter Experience

Each voter first approached a welcome table located outside the polling room. After signing a consent form, the voter proceeded to an adjacent check-in table. There, a poll worker looked up the voter's name in a poll book and issued a voter authority card. The voter then entered the polling room and presented the voting authority card to poll workers at the ballot issue table, who issued a Scantegrity ballot secured to a locked clipboard with privacy sleeve (see Appendix B).

The voter proceeded to one of three voting areas, each with a cardboard privacy shield. Using a special pen with revealing ink, the voter marked her ballot choices by marking the selected ovals with the pen. The revealing ink exposed a two-character confirmation code in each marked oval. Optionally, while also using the special pen, the voter could write down these confirmation codes on a detachable ballot chit, treated with reactive ink. As required by Takoma Park for municipal elections, Instant Runoff Voting (IRV) [Pou08] was used, so each voter was asked to rank each candidate in order of preference.

Appendix A shows the Mock1 ballot, which featured four questions about trees. To avoid possible confusion, Takoma Park officials required that races on our Mock1 ballot not resemble those on official ballots. November's official ballot had two races (mayor and ward council member) per ward. The municipal election can also have ballot questions.

Instead of voting on the issued ballot, each voter had the option of performing a "print audit" to verify that the ballot had been correctly printed. To do so, the voter walked to a voter assistance table and followed instructions from a poll worker. The poll worker marked the ballot spoiled and exposed all confirmation codes. The voter was permitted to copy information from the ballot to take home. A poll worker then escorted the voter back to the ballot issue table to receive another ballot. Each voter was allowed to receive up to three such ballots. We used a similar procedure if the voter unintentionally spoiled a ballot (e.g., by marking the wrong choice).

After marking the ballot, the voter proceeded to the scanning table. A poll worker unlocked the ballot from the locked clipboard and scanned the ballot. Looking at a touch-screen display connected to the scanner, the voter confirmed that the ballot was scanned. Without showing the voter's ballot choices, the touch-screen display warned the voter if the scanner detected any over- or under-voted questions. At this point, the voter could either return to the voting area with the ballot or cast the ballot by pressing the cast button on the display. The poll worker then tore off the chit and gave it to the voter, and dropped the ballot into the ballot box. Throughout the scanning process, a privacy sleeve hid the ballot choices. The chit provided instructions on how the voter could optionally verify her vote online after polls closed.

3.2 Research Protocols

Any consenting adult who showed up was permitted to vote. At the request of Takoma Park, to encourage children to become involved in voting and new voting technology, assenting children twelve to seventeen years old were also permitted to vote, with parental consent. We advertised the event through e-mail, Web pages, local TV, and in the Takoma Park Newsletter [TPN09]. Despite the rain, 105 people signed consent forms.

Sitting in the polling room in the place reserved for official observers, two unobtrusive observers watched as many voters as possible, filling out voter observation sheets. Each observer recorded the time an observed voter spent from receiving a ballot to casting it. Each observer also noted how many times the voter spoiled a ballot, requested or received assistance from a poll worker, or appeared confused.

As each voter left the polling room, a researcher asked the voter if she would be willing to fill out a questionnaire. If yes, the researcher handed the voter a conventional clipboard with two two-sided questionnaires: a voter field test questionnaire and a demographics questionnaire. Form numbers linked the field test and demographics questionnaires filled out by the same voter.

As the voter returned the clipboard, the researcher asked the voter if she would be willing to return at 3 PM that day for a one-hour focus group. For each such willing voter, the researcher wrote down a telephone number and the demographics form number. The plan was to call eight of the willing voters, reflecting a diverse sample of voters as determined solely from the demographics form. However, given that only twelve of the 80 voters filling out questionnaires agreed to participate in a focus group, we invited all twelve willing voters, of whom four showed up.

We also conducted a separate one-hour focus group for all six poll workers as soon as possible after polls closed. Each poll worker also filled out a poll worker field test questionnaire and demographics form.

Voters could visit the online verification web site after polls closed. After providing consent and verifying their votes online, they were invited to fill out an online verification questionnaire and a short demographics form.

Aside from the consent form and list of telephone numbers on the focus group sign-up sheet, we did not collect any personal identifying information.

Originally, we had planned to link each voter's demographics questionnaire to her observation sheet and ballot (and thereby to her verification questionnaire). Ultimately, we decided not to do so, to avoid interfering with the election process, and to avoid creating the appearance of violating ballot privacy. Instead, we added a second short demographics questionnaire to the online verification experience.

For Mock1, Takoma Park poll workers and Scantegrity team members worked side-by-side to help the poll workers learn how to operate the system. By contrast, in the binding election in November, poll workers operated the system entirely by themselves.

4 Results

This section summarizes data collected from our research instruments, including the voter demographics questionnaire, observations sheets, voter field test questionnaires, online voter demographics and verification questionnaires, and the voter and poll worker focus groups.

4.1 Unobtrusive Observations

Figure 1 summarizes observations made by two unobtrusive observers watching fifty-three of the voters. The main difficulty was the length of time it took to vote, averaging about eight minutes from the time a voter received a ballot to the time the voter cast the ballot (not including time for check-in or instructions given before voter received a ballot). Much of the time was observed to be at the scanner table.

When voters asked for assistance and/or poll workers intervened, it was typically either because the voter did not know what to do after marking the ballot, or because the voter did not know what to do upon spoiling a ballot.

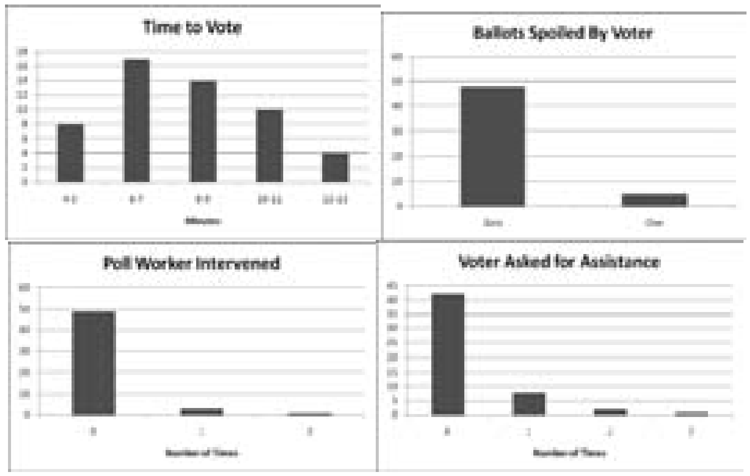

Figure 1: Summary of data from unobtrusive observations of 53 voters.

4.2 Voter Demographics

Figure 2 summarizes voter characteristics of the eighty voters who filled out paper demographics questionnaires. These voters were not representative of the Takoma Park voting population. They had high family incomes and were highly educated, frequent computer users, mostly fifty to sixty years old, motivated, and able to get to the mock election on their own.

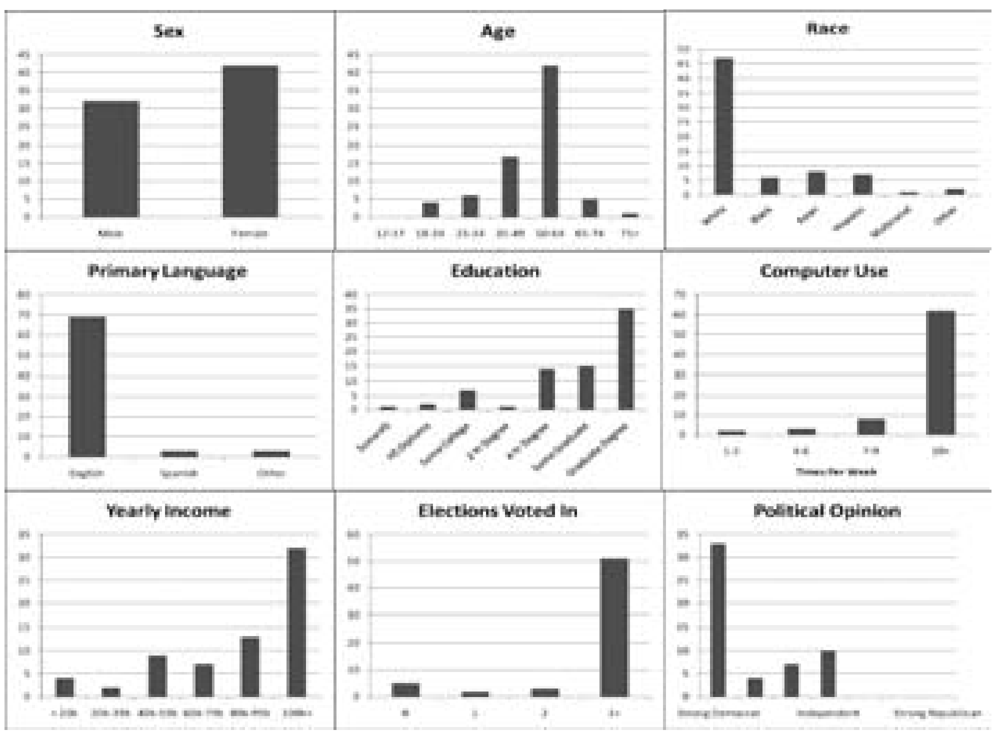

Figure 2: Summary and comparison of voter demographics from 80 responses to a paper questionnaire filled out by voters immediately after voting.

4.3 Voter Field Test Survey

Figures 3 through 6 summarize data collected from eighty field test questionnaires filled out by voters immediately after casting their ballots. We include all responses, even though it was apparent (from implausible answers to questions about ease of correcting errors and understanding of cryptographic details) that three respondents had likely reversed the seven-point Likert scale.

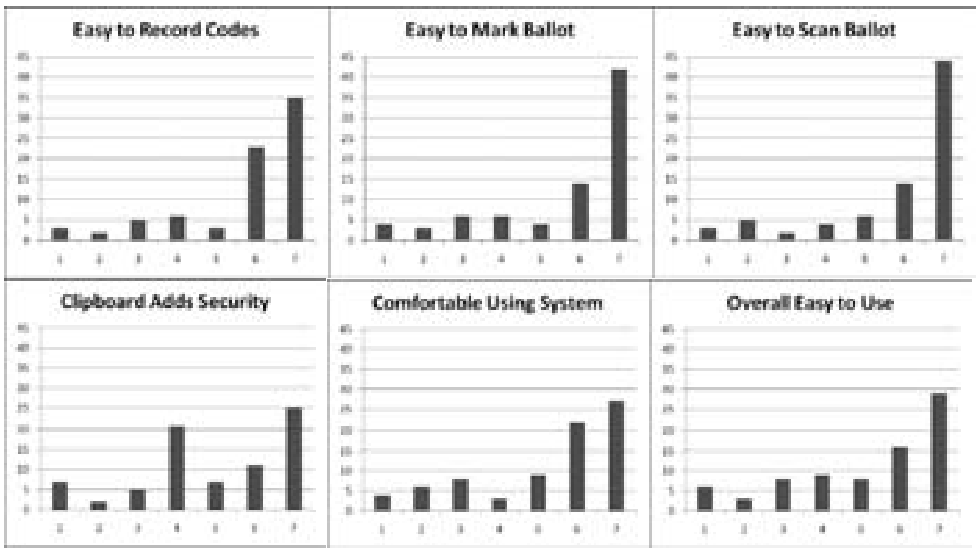

Figure 3: Summary of 80 responses to a paper questionnaire about Scantegrity filled out by voters immediately after voting.

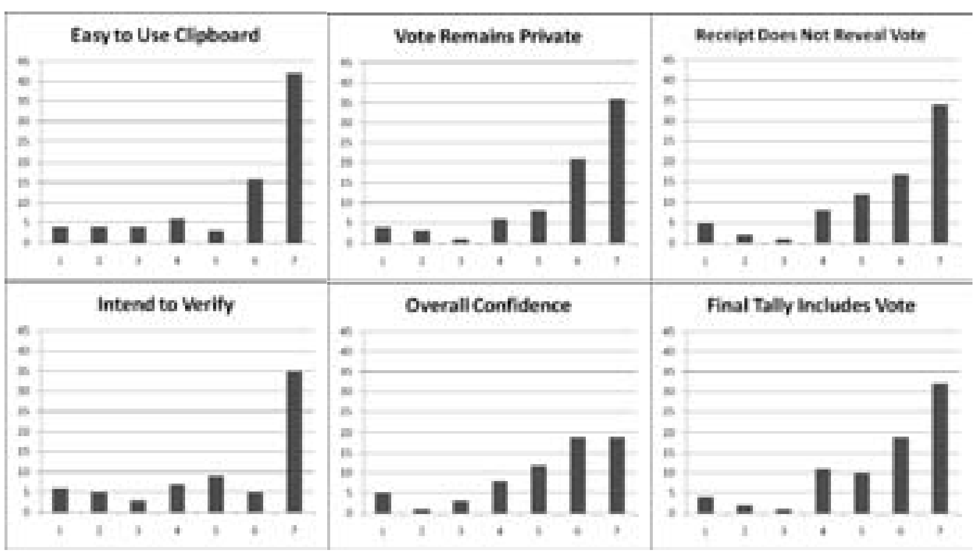

Figure 4: Summary of 80 responses to a paper questionnaire about Scantegrity filled out by voters immediately after voting.

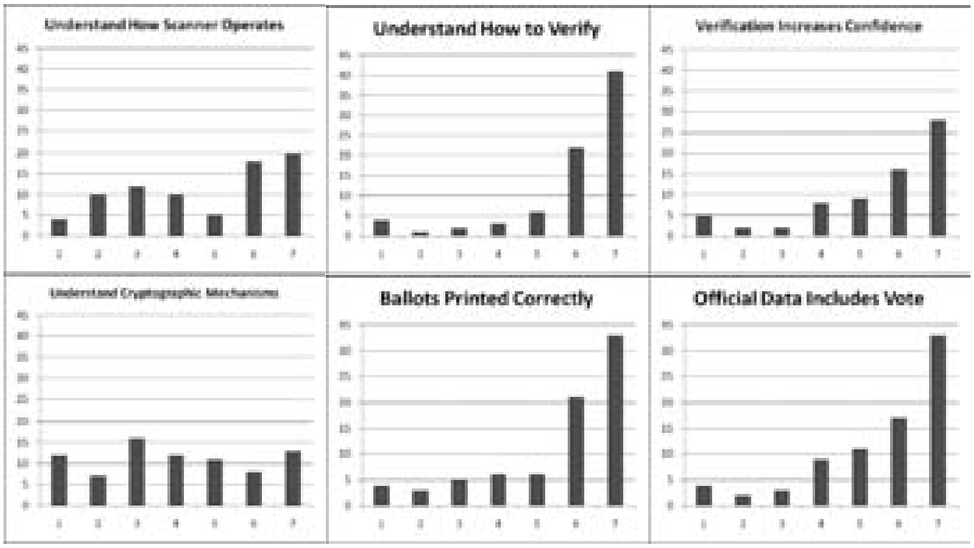

Figure 5: Summary of 80 responses to a paper questionnaire about Scantegrity filled out by voters immediately after voting

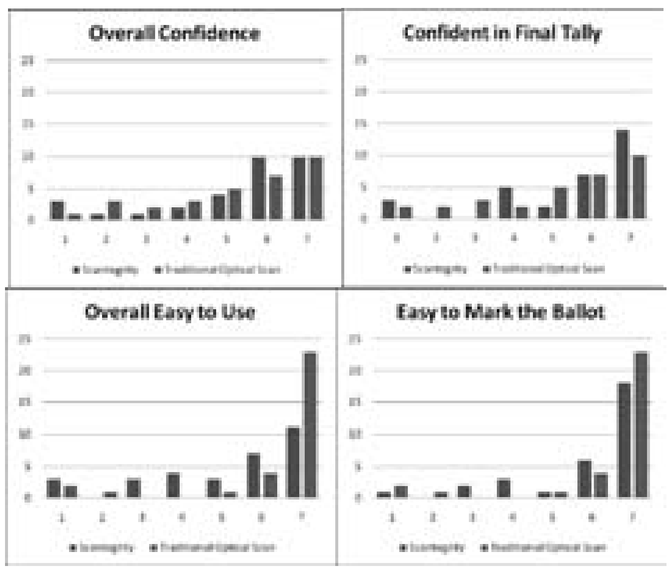

Figure 6: Summary of 31 responses to questions about Scantegrity and a comparison to answers from those same responders about traditional optical scan systems based on their recollection of their last experience with an optical scan system (1 = strongly disagree, 7 = strongly agree)

4.4 Online Voter Verification Survey

As of April 15, thirty-one voters verified their votes online. Seven of these voters completed the associated online questionnaire. Table 1 summarizes the responses from these seven voters.

Q		1	2	3	4	5	6	7
1	I was able to complete the verification process.	0	1	0	0	0	2	4
2	I verified that my votes were correctly recorded as cast.	1	1	0	0	0	2	3
3	The verification system was easy to use.	1	0	0	0	0	1	5
4	I feel comfortable using the verification system.	1	0	0	0	0	3	3
5	I am confident the official data includes my intended vote.	0	1	0	2	1	1	2
6	I am confident the final tally includes my intended vote.	0	1	0	3	0	1	2
7	I am confident my vote is and will remain private.	0	1	0	1	2	2	1
8	Online verification increased my confidence in the results.	1	2	1	1	1	0	1
9	I understand how the online verification system works.	0	3	1	0	0	1	2
10	I have confidence in the online verification system.	0	1	0	4	1	0	1
11	Overall, I have confidence in Scantegrity.	0	0	1	3	2	0	1

Table 1. Summary of all 7 responses from the online verification questionnaire (1 = strongly disagree, 7 = strongly agree).

4.5 Voter and Poll Worker Focus Groups

Four voters participated in the voter focus group. These came from the twelve voters who stated they might be available to participate, all of whom were invited. These four voters were not representative of the Takoma Park voting population: they were involved with municipal functions and some had helped bring voters to previous elections.

All six Takoma Park poll workers participated in the poll worker focus group. Each was experienced and had worked previous elections in Takoma Park. None are part of the Scantegrity Team. Because both groups expressed similar thoughts, we now summarize the main comments from both groups together, as reported by the moderator [Bau09]:

1. The process took too much time.
2. Providing instructions in one chunk at beginning was overwhelming.
3. The instructions were too complex, and there was too much explaining.
4. Although the voters in the focus group did not experience difficulties voting, some wondered if other voters in Takoma Park might experience difficulties writing down confirmation codes and verifying their votes online.
5. Vote casting at the scanning table took too much time.
6. Some poll workers disliked that a poll worker handled the ballot during scanning.
7. The scanner was finicky.
8. During scanning, the poll workers liked the feedback of seeing light on a flash drive blink, suggesting that the ballot was read.

9. The locked clipboard added time and complexity, but did not increase security.
10. Make the special pens available only in the voting area.
11. Poll workers felt that they should have been more in charge, especially of the flow of voters around the room.
12. Poll workers felt that the process could be sped up to make it viable for the binding election.

Finally, the moderator [Bau09] emphasized, "It is critical that all instructions are tested ahead of time on a range of people representative of the wider Takoma Park population to ensure they are clear and understandable" and that "[t]ranslations into other languages must also be tested."

5 Discussion

The main two issues were that the process was too slow (taking about eight minutes to vote on average) and many voters found the instructions somewhat complicated. Much of the delay was caused by the scanning process and lengthy instructions given to voters. Fortunately, these problems are solvable through process simplification and improvement, better scanners, and careful human-factors testing.

Although there has been tremendous simplification of Chaum's ideas from SureVote, through Punchscan to Scantegrity, the team had spent relatively little effort on testing and perfecting the human-factors details of the voting process, especially when carried out by typical voters. Some Mock1 voters were enthusiastic about the security features of Scantegrity, but most seemed not to care much about security, focusing primarily on the physical process of receiving a ballot, marking the ballot, and scanning the ballot. While such voter reactions are well known from the social science literature, it was nevertheless a dramatic learning experience to witness these reactions first-hand.

Although the Mock1 voters and participants in the voter survey group were not typical Takoma Park voters (many were self-selected as having an interest in the voting system to be used by the city, and some were just there to participate in the Arbor Day celebration), they provided useful feedback and expressed awareness of potential issues that might affect other voters. Factors affecting the slow voting process included lengthy instructions, redundant instructions, instructions for optional steps, use of the locked clipboard, writing down confirmation codes, tearing off the ballot chit, difficulty of correcting mistakes (for the few who unintentionally spoiled ballots), checking for over- and under-votes at the scanner touch screen, and a slow, finicky scanner.

Our scanner caused significant problems. Ballots had to be inserted in a particular orientation. If they went in at too much angle, a corner could be unread. Some voters seemed confused that the touch screen did not show how they voted, but only for each race whether the race was over- or under-voted. After the voter pressed "cast," feeding the scanned ballot into a privacy sleeve and dropping the ballot into a large ballot box was clumsy. Although these equipment, implementation, and process problems can be fixed, they would have created severe difficulties in an election with over 2,000 voters.

The locked clipboard worked poorly. It complicated and slowed down the process, made it difficult to drop ballots into the scanner, and added weight. Most voters felt it did not enhance security, despite its purpose of making it difficult to steal or swap ballots. At the scanning table, several voters mistakenly ripped their ballots off the locked clipboard. Technically, any ballot with torn locking hole was supposed to be invalid, but for simplicity this rule was not enforced.

Some elderly voters commented that they had difficulty reading the confirmation codes. Three voters reported that some confirmation codes blurred, especially if rubbed heavily, and one reported that the ballot paper deteriorated. On a positive note, marking the ballot with revealing ink produced perfectly darkened ovals: because there was no reactive ink outside the ovals, no darkening appeared there. Although this outcome was not the motivation for printing Scantegrity ballots with invisible ink, it appears evident that invisible ink yields a superior method for marking optical scan ballots. We supplied pointed "bullet" style special pens, to facilitate writing down the confirmation codes. Wider "chisel" style special pens, however, seem to work better for marking ovals.

Figure 7 shows correlations between survey responses on age and ease of use, and between understanding of Scantegrity and overall confidence in the system. As expected, overall, older voters found Scantegrity harder to use than did younger voters. Interestingly, most voters still had high confidence in Scantegrity, even if they felt they understood the system poorly. This finding runs contrary to a widely asserted notion that voters will not accept a system that they do not understand.

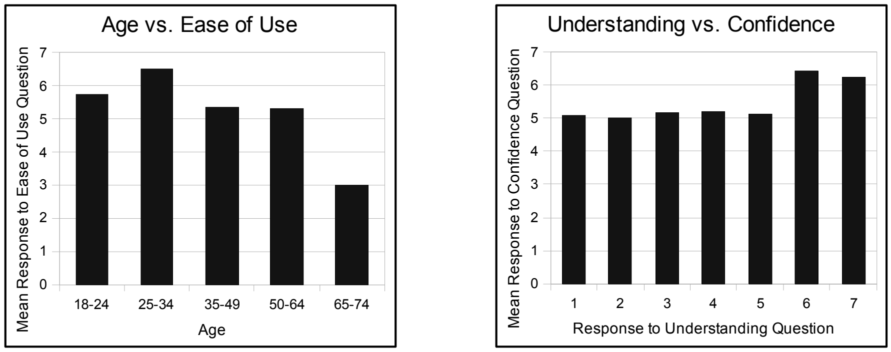

Figure 7. Correlation between age and overall ease of use, and between understanding and overall confidence in system. Voters under 65 years of age found Scantegrity easier to use. Voters who felt they understood the system very well had slightly higher confidence in the system, yet even those who felt they had a poor understanding of the system had a moderately high confidence in the system. Pearson correlation coefficients: age vs. ease of use: -0.20, understanding vs. confidence: 0.28. (1 = strongly disagree, 7 = strongly agree)

6 Recommendations

To simplify and streamline the process, we recommend the following:

1. Eliminate the locked clipboard.
2. Eliminate redundant instructions. At beginning of process, do not provide instructions for optional steps.
3. Use high-quality, fast, robust scanners—preferably of the type that automatically drops the ballot into the ballot box when the voter signals to cast the ballot. The scanner should accept ballots inserted in any orientation.
4. Add a printer to the scanner to provide a digitally signed receipt with the confirmation codes. Great care must be taken to ensure that this printer does not violate ballot privacy (Fink and Sherman [Fin09] suggest one approach).
5. Eliminate the tear-off chit. Instead, provide a separate sheet of paper to any voter who wishes to write down confirmation codes or other ballot information by hand.
6. Print confirmation codes with a restricted character set to avoid easily confused letters.
7. Use “chisel” style special pens for ease of marking ovals, selecting a small enough chisel width to permit writing down confirmation codes and write-in candidates.
8. Thoroughly analyze and test the voting process with many diverse voters.

7 Conclusions

The mock election demonstrated that Scantegrity can be effectively used in elections and is well accepted by voters. Survey data show that voters feel comfortable with the system and have confidence in it.

Mock1 revealed though that the flow of people through the voting process must be greatly improved. The implementation, procedures, voter instructions, and equipment of Scantegrity used in this election need to be simplified and streamlined. Although Scantegrity significantly simplifies the voting process from its predecessors SureVote and Punchscan, additional attention is needed to improve and fine tune the voter experience, including the physical processes of receiving, marking, and scanning the paper ballot.

After polls closed, thirty-one of the ninety-five voters verified their votes online, demonstrating that a sufficient number of voters will likely take advantage of the verification option in E2E systems. This percent of voters verifying their votes is consistent with that observed in our other Punchscan and Scantegrity trials. We conjecture, however, that in binding elections, the percentage will also depend on the degree of interest in and contention of the races.

Our findings include that the locked clipboard added complexity, but did not enhance security, and that revealing ink provides a superior technology for marking optical scan ballots with perfectly darkened ovals.

Even though many voters do not care much about security and tend to trust voting systems, a small and vocal group of political activists is very concerned about this issue. Deploying systems like Scantegrity fundamentally enhances outcome integrity and directly addresses those activists concerns.

Accessibility for voters with disabilities was not a focus of this study. In separate projects, our team is seeking better solutions for the vital challenge of making high-integrity voting truly accessible to differently-abled voters, including the blind.

Learning from Mock1, we implemented the following changes for the subsequent binding election: eliminated the locked clipboard, designed a new privacy sleeve, eliminated the monitor check at scanning, added a second scanner, built ballot feeders for the scanners, used a double-ended pen with chisel and bullet points, eliminated redundant instructions, improved signage and instructions at registration and in the voting booths, and used a separate receipt card rather than a tear-off chit.

Mock1 helped pave the way for Scantegrity's successful deployment in the November 2009 binding governmental election in Takoma Park [Car10]. Lessons learned from this feasibility demonstration helped streamline voter flow, reduce average voting time (from 8 min to 2.5 min), and improve instructions to voters.

8 Acknowledgments

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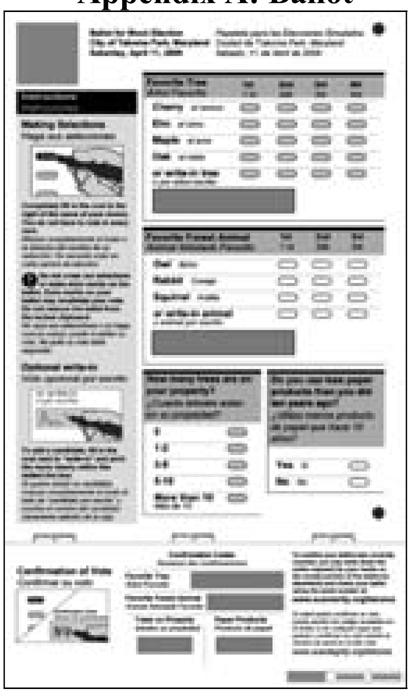
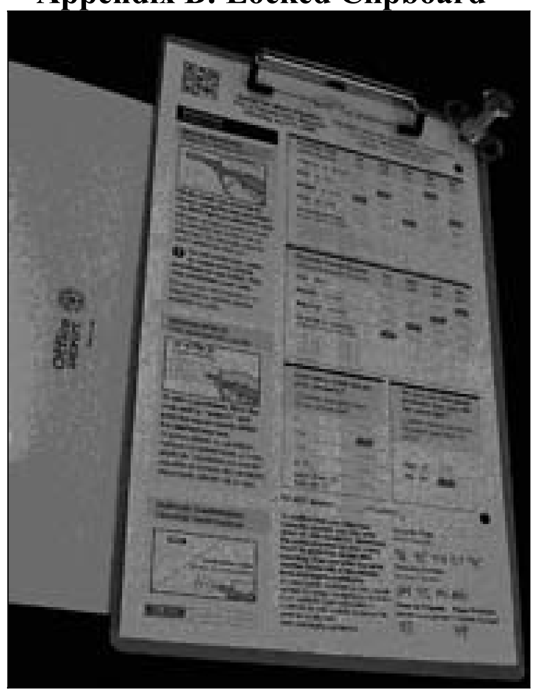
Appendix A: Ballot



Ballot shown smaller than actual size.

Appendix B: Locked Clipboard



Locked clipboard resists chain voting.