**NIST Voting Project**

# A report of the research: How voters review & verify ballots

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# Introduction

This is a report of qualitative research to gain deeper insights about how voters mark, review, verify, and cast their ballots. It was conducted as part of the work to update the human factors—accessibility, privacy, and usability—requirements in federal voting system standards and fill gaps in our understanding of how voters interact with ballot marking devices.

## Background

The Help America Vote Act of 2002 established requirements for voting system standards to enable uniform and nondiscriminatory election technology and administration. One of the most ground-breaking sections of that law requires the Elections Assistance Commission to create standards for voting systems that enable people with disabilities to vote "in a manner that provides the same opportunity for access and participation (including privacy and independence) as for other voters."  It also requires that voters be able to verify their vote selections, and have an opportunity to make changes, before their ballot is cast and counted.

Two versions of those voting system standards, the Voluntary Voting System Guidelines, 1.0 in 2005 and 1.1 in 2015, were adopted. Both contained detailed requirements for usability and accessibility. As work began on a new version, VVSG 2.0, a new kind of voting system was widely adopted. Generically called ballot marking devices (BMD), these systems are a hybrid of an electronic marking interface offering accessibility and a voter verifiable printed ballot that is cast in a precinct or central count tally system, similarly to hand-marked ballots.

Most human factors research on electronic marking interfaces has focused on the usability and accessibility of the marking process, with special emphasis on the final review screen that allows for confirmation (or changes) to selections before casting. In a gap analysis of the existing requirements, it became clear that there is not enough research evidence to establish best practices for making a ballot printed by a BMD verifiable and as accessible as it is possible for a paper artifact to be.

# Why verification matters

Broadly, the goal of the voting system standards is to ensure that voters can cast a ballot that reflects their intent. In this, usability and cybersecurity both play a role:

- Good usability helps ensure that that ballot does not contain **errors** made during the selection and review process, including selection mistakes and unintentional undervotes.

- Strong cybersecurity helps ensure that the final ballot has not been **maliciously changed** from the voter's selections.

Both are important for voters, candidates, and election advocates to trust that the results of an election fairly reflect the will of the voters.

Arguably, there is evidence that marking errors on both paper and electronic interfaces might have influenced the results of an election. These include the infamous "butterfly ballot" in Palm Beach County, FL in 2000 in which misaligned and unlabeled ballots seem to have caused some voters to make an inaccurate selection, ballots in Sarasota County (2006) and Broward County (2018) that caused an unusual number of voters to skip a hotly contested race, and a Senatorial contest in California with 34 candidates that had a high number of overvotes on hand-marked ballots.

Reducing the number of errors is an important goal. Much of the usability and accessibility research has focused on design best practices that will help voters make their selections accurately, prevent overvotes, and identify undervotes— missed opportunities to participate.

Cybersecurity experts argue that it is an equally important goal for voters to be able to accurately verify the final printed ballot to be sure that the system itself has not changed the selections. Much of the research on verification consisted of studies in which voters use a malicious experimental system that changes votes on the review screen or printed ballot. The researchers in those studies assess success by counting the number of participants who find the changed selections before casting their ballot.

The results of most of these studies has been poor, with as few as 25% finding the anomalies on randomly voted ballot. As many as 60% found the anomalies

when they had been given instructions about who to vote for. One study used a voting system which paired a deliberately slow review process with a clearly designed printed ballot. Using this ballot marking device, 90% of the participants found the errors.

One challenge in considering the impact of these studies on elections is that there is no consensus about what percentage of voters would have to notice a problem to be sure that an attack on machine-printed ballots would be detected before it could affect the outcome of an election.

## Goals for this research

Unlike the studies of error detection, this study takes a qualitative approach, focused on observing the act of voting—marking, reviewing, verifying and casting a ballot—and interviews with participants before and after each interaction.

Both the observations and interviews probed the role the design of the voting interaction and overall voting process plays in encouraging voters to carefully check their ballot before casting it.

The specific questions that this research aimed to answer are:

- How might we design voting systems and voting processes that support ballot review and verification, so all voters can mark, verify, and cast their ballot as they intend?
- What specific elements of the interaction and ballot design encourage accurate review and verification as part of the voting process?
- What design and layout of a printed ballot makes it easier for people with disabilities to verify their ballot?

## Definitions used in this report

We have used specific terms to identify the key activities and artifacts in this study to avoid confusion.

**Ballots.** All of the voting methods used in this project included a paper ballot. To make the differences clear, we refer to:

- **Hand-marked ballots** are pre-printed ballots to which voters add marks with a pen to indicate their selections. The ballots used in the research are "bubble-style" ballots with an oval marking area adjacent to the printed option or candidate name.
- **Printed ballots** are produced by a BMD to be cast separately. The BMD-printed ballots can be either bubble-style, with the marks made by the printer, or a summary list of the contests and voter's selections and non-selections in each contest.

**Marking, review and verification.** To be able to compare hand-marking and using a BMD, we defined these activities and the point at which a voter transitions from one to the next.

- **Marking** covers the period of time when the voter marks their selections in each contest.
- **Review** is the final activity of the marking stage:
  - On a BMD, this takes place on the review screen. It includes any corrections to selections in a contest made from the review screen.
  - On a hand-marked ballot, it covers any time re-checking the ballot after initial marking.
- **Verification** is the act of checking the ballot as it will be cast:
  - For a BMD, verification can only take place with the final printed ballot before it is cast.
  - For a hand-marked ballot, review and verification are blurred because the voter is marking the paper ballot that will be cast. For consistency in our note-taking, we identified the boundary between review and verification as the point when the participant stood up to walk to the scanner.

## Further research needed

Every research project answers some questions and opens new questions for future research. Additional research is needed to more fully answer this core question:

How can we design the electronic voting experience so verification becomes a normal and expected part of the process?

Specific questions focus on all of the materials of voting:

- What change to the design of the printed ballot itself would encourage verification and help voters understand that the paper printed by the BMD is the official ballot, not a receipt?
- How can voter education balance the need to communicate the importance of verification, without reducing trust in elections?
- What design of a polling place setup, including signage, instructions from poll workers, or other materials can improve the number of voters who effectively verify their printed ballot?

Another area for further research is collaboration between all of the researchers working on verification. The triangulation of research approaches and input from practices in related disciplines (computer science, cybersecurity, psychology, accessibility, and usability) could be helpful in thinking through the trade-offs and balances of election principles and guidelines.

# How we ran the study

This was a qualitative study, focused on observing participants as they voted.

Each participant voted twice, first using a hand-marked paper ballot and then one of three ballot marking devices (BMDs). After each of the voting sessions, we interviewed them about their experience allowing us to confirm observations and clarify their intent.

The ballot had 14 contests, based on the NIST "minimum complexity ballot" for certification usability tests.

- The hand-marked paper ballot was designed to the Election Assistance Commission's best practices. It was printed on two sides of legal-sized paper.
- The three BMDS are either already certified to federal standards or are being developed towards certification. Two printed summary-list ballots; one printed a bubble-marked ballot similar to the hand-marked ballot we created for the test.

To enable us to observe people voting, we set up each research location with some elements of a polling place. Participants checked in at a front desk before the initial interview. Then, they went to a separate table or voting station to mark their ballot. Finally, they cast their vote in a ballot box (standing in for a precinct scanner) or for one of the systems, at the voting station. Although the voting experience plays an important part in shaping voting behaviors and attitudes such as trust in the election, this study is not a test of the voting systems. We have noted differences in the system architectures and interactions in Appendix D.

➔ See Appendixes B, C, and D for test materials and details of the voting systems.

The sessions were conducted in three different cities, to ensure not only diverse participants but a natural diversity in the types of election procedures and voting systems they are used to.

There is also evidence in the literature that personal characteristics such as a history of voting experience, abilities of the voter to interact with the voting

system, and level of interest in and knowledge of the candidates and issues on the ballot also affect voting behavior.

We looked for a diverse group of participants. All were registered voters, but they had a range of voting histories, personal ability - including disabilities and low literacy, and education levels.

➔ See Appendixes E and F or details of the participants in this study.

In addition to the data and insights from the participants in this study, we used information from the published reports of the Pennsylvania voting system certification testing with voters with disabilities (also conducted by Center for Civic Design).

## Creating a realistic voting experience

One of the biggest challenges with doing research about voting is making the event feel like a real election, while leaving political opinions out of the process.

We constructed the activities in this project to focus on behavior—how and why people mark, review, verify, and cast their ballot—rather than who they choose to vote for.

We also wanted to make the voting process meaningful so that participants would be invested in the process and have clearly expressed intent for at least some of the contests.

To do this, we:

- Followed the NIST suggestion to use realistic, but not real, names for the candidates and lightly adapted real ballot questions.

- Used historical party names, so they would sound familiar, but not be identified with current politics.

- Created a 4-page voter guide that provided: brief campaign slogans for all the parties, a list of all the contests on the ballot, and brief statements for three contests we were asking the participants to focus on.

During the opening interview for the session, we asked participants to read the voter guide, use it to make decisions about who to vote for in the three contests, and talk to us about what attracted them to the parties or candidates they chose.

We used this conversation to solidify their choices by having them vocalize what drew them to those choices.

The three contests were:

- Governor: A vote-for-one contest with 13 candidates in 6 parties and 7 independents
- City Council: A vote-for-three contest with 5 candidates in 2 parties
- A ballot question about gambling, a topic on which we expected participants to already have at least a mild opinion

Candidate statements included their party, web site address, and a brief slogan–written to be lightly amusing, but reflect real issues in elections.

**Sample candidate information in the voter guide**

# City Council

The people elected to the City Council make laws, set policies, and manage projects to improve the city of Springfield.

→ You may vote for up to 3 people.

| Harvey Eagle | Randall Rupp | Carroll Shry | Beverly Barker | Jin Chen |
|---|---|---|---|---|
| Federalist Party | Federalist Party | Federalist Party | People's Party | People's Party |
| EagleEyeHarvey.org | RandyRupp.win | ShyShry.org | BevBarBar.net | chenFTW.org |
| You know we're right. Business is where it's at. We need to rezone and build more malls. | I make the hard choices. I do what needs to be done. I'm your guy. | I will lead with integrity, honesty, and commitment. | I have 5,000 Facebook friends. I want to be your friend too. | I represent people, not politics. I want to unite all views. |

→ See Appendix B for the complete voter guide

# Limitations of the research

The most important limitations of this research are common to all research involving a mock election: you can only simulate a real election to a limited extent. Most participants gave careful attention to the two voting activities, using the voter guide in a serious way, and followed their voting plan.

But there were also a few participants who got distracted by "trying out" the ballot-marking device and voted randomly. This made it harder to determine the match between their intent and how they marked the ballot, even after asking them about it in the follow-up interview. It also extended the time it took to mark their ballots, especially when they tried writing in a candidate.

We had good demographic diversity of participants, but did not have many who were infrequent or non-voters because the recruiting materials made it clear they would be giving feedback on a voting system.

Some of the participants were bilingual, but the research was conducted in English, so some proficiency in speaking and reading English was required.

We included participants with a range of physical, visual, and cognitive disabilities, but did not include blind voters who would use the audio format or voters with no use of their hands. We did, however, include findings from other voting system testing with voters with those disabilities, as discussed below.

Although we use some quantitative analysis, with only 35 participants using three different BMDs, we do not draw any statistical or predictive conclusions from this study. We report quantitative counts where it is helpful in understanding our results or in seeing trends in the behaviors we observed.

# What we learned: Four big themes

As we sifted through the detailed observations of 70 voting sessions and 35 interviews, some big themes emerged about the influences that shape attitudes and behaviors about voting:

- Past voting experiences shape expectations for the voting process.
- Voters preferred ballot marking devices.
- Voters did not have strong habits for verifying their printed ballots.
- Ballot marking devices did not encourage verification of printed ballots.

We discuss these themes in detail in this section.

## Personal experiences shape expectations for the voting process

### Past voting experience and the local voting system affect expectations

Every voter has a mental model of the voting process based on their voting experiences and their experiences with technology. This might include expectations about how they cast their ballot or modes of interacting with the electronic marking interface. And, it may affect their reactions to new ways of voting.

For example, participants with experience using hand-marked ballots had trouble identifying when their BMD-marked ballot was actually cast or whether the printed ballot was their official ballot or some kind of receipt.

> "I didn't expect it to print. Then I didn't know what to do with it. I thought it was just my copy to keep."
> *Los Angeles voter with previous experience on InkaVote*

This was a qualitative study with a small number of participants, but there were enough comments and observations to suggest that instructions to verify the printed ballot should take the local election history and culture into account.

➔ See Appendixes E and F for details of the participants in this study

## Personal characteristics affect behavior during voting

Personal ability and levels of civic engagement also make a difference. The participants in Baltimore had, as a group, the most accessibility needs and the lowest levels of education. However, they were also the people most likely to carefully review their selections and verify their ballot.

- All of them took care in marking
- All but 1 used the review screen carefully
- Two-thirds made some attempt to verify the printed ballot.

Differences in how carefully an individual marked the ballot and reviewed their choices can be seen in the time taken for each of these activities. The fastest voting times were barely a minute—typically for participants who chose to vote *only* for the three contests the voter guide focused on. The slowest voting times were as long as 13 minutes.

There were also differences in how persistently they worked to make sure their ballot reflected their intent. One participant requested a new hand-marked ballot when after making a mistake, and some worked carefully to understand undervote notifications on the review screen. But others decided to cast a ballot knowing there were mistakes. This may be an effect of the test environment, but may also be true in the polling place, seeking to avoid calling attention to themselves by asking for help or not wanting to take any more time.

## Participants did not always follow their voting plan

It could be hard to tell whether a change in selections was a mistake, or a deliberate change in plan.

We looked for signs that they were taking the voting task seriously in

- How closely their ballot selections matched their voting plan
- How consistent their ballots were to each other

- Whether they had a clear explanation for the differences

# Voters preferred ballot marking devices

At the end of the session, after they had used both ways of voting, we asked participants whether they would want to use a BMD or hand-marked paper ballot in the next election.

Overall, over two thirds of the participants (25/35) said they preferred using a BMD.

No matter which system they used, participants who preferred the BMD said that it was easier and gave them more confidence voting. Several emphasized the ease of identifying and correcting *errors*–marking mistakes.

Those who preferred the hand-marked paper ballot tended to focus on concerns about technology rather than positive aspects of the voting experience. But there were also many comments about the difficulty of marking a hand-marked ballot and the challenge of correcting a mistake.

> "I try to fill in that circle as best I can… sloppiness may cost someone a vote."

> "I hated filling in bubbles.  Never been a fan - always worried."

> "The one part I didn't like that because I was using a pen and I had started marking someone and then hesitated...and knew I couldn't just X it out. I figured was easier to go with that candidate because didn't really know anything about the contest."

> "It said not to mark outside the oval, but that's hard to do. So I try to do a little and then move out [to the edge of the marking area]."

**Reasons cited for preferring a BMD or hand-marked ballot**

| Those who preferred the ballot marking devices said | Those who preferred hand-marked ballots said |
|---|---|
| • Clean, modern, and inviting | • You can see all the names in a contest at the same time |
| • Easier to read | • Feels more trustworthy |
| • Easier to mark selections | • Concern for glitches with technology |
| • Easier to change selections | • [System A] Frustration with touch problems on the screen |
| • Easier to focus on one contest at a time | |
| • Felt faster or more efficient | |
| • More fun | |
| • Less error-prone than filling in bubbles, more confident that it'll be read correctly when scanned | |
| • Lots of places to double-check and catch mistakes | |

The preference for ballot marking devices was especially strong among participants with disabilities, whether they had physical disabilities that affected their ability to interact with the system, cognitive issues such as trouble concentrating and anxiety, or low literacy.

> "The layout of the [hand-marked] ballot was clear however, for whatever reason, it felt jumbled to me today. One page per issue would be easier. [The BMD] was quiet - that was nice. And ample space to look at the voter guide."

> "It takes a little longer to really read it [hand-marked ballot] out and really see what you want. It's not hard. Everybody don't read the same."

They gave the same reasons for their preference as everyone else, but were more emphatic about it. One called it "infinitely easier." Another said "I'll take the machine any day."

## The usability of the voting process can affect acceptance of ballot marking devices

There was a difference in the preference for BMD vs. hand-marked ballots among the three different voting systems used.

**Preference for BMD or hand-marked ballot by BMD used**

| BMD used | Preferred BMD | Preferred hand-marked |
|----------|:-------------:|:---------------------:|
| System A | 4 | 7 |
| System B | 13 | 2 |
| System C | 8 | 1 |
| Overall | 25 | 10 |

We believe the combination of several elements of the voting experience contributed to this difference in preference results between participants who used the three different BMD systems:

- **Usability issues.** Many participants who used system A had trouble using the touch screen to make selections or activate controls because of a delay or touch sensitivity, making it difficult to use.
- **Elections culture.** The test location for system A has a strong tradition of hand-marked ballots.
- **Ballot style.** System A printed a bubble-style ballot, reducing the number of differences between the two types of voting.

## Hand-marked ballots are difficult for some voters to use

A surprising number of participants expressed anxiety about the difficulty of marking a hand-marked paper ballot and whether they were filling in the bubbles

accurately. Although it was mentioned by a wide-variety of participants, the sentiments were strongest among the participants with the most challenges in participating in elections.

- Reading the ballot instructions and focusing on one contest at a time, especially with low literacy participants.
- Mild physical dexterity issues, making it hard to fill in the ovals completely.
- Concern they won't fill in the ovals well enough for their ballot to be scanned correctly.

> "You really have to pay attention to separate [the contests]"
> *Participant who read across the three columns instead of following the "newspaper" order of the ballot*

Some participants even likened it to taking a test. When they said that filling in bubbles was like a test, they meant that it was a stressful situation in which they feared they would make a mistake. And they described strategies that reflected their conflicting views about the task of marking a ballot as something hard to do.

> "The bubbles are like taking a test."

> "To leave it blank is like not voting at all."

> "Eeney, meeney, miney, moe... I'll get most of them right."

## Ballot marking devices did not encourage verification of printed ballots.

As the voters marked, reviewed, verified, and cast their ballots, we observed carefully for how they checked their work at each stage.

We observed whether they worked in a deliberate manner, checking both the marks and their notes with their voting plan, or skipped through each stage of voting quickly.

## Voters trusted their careful checks while marking

In general, people were careful and deliberate in making their selections, regardless of how they were voting.

But some made mistakes. They skipped contests or marked a candidate other than the one they said they wanted to vote for. Many undervoted in one or both of the contests that allowed multiple selections because they never saw the instructions to vote for more than one candidate.

> "Oh, I didn't realize I could vote for more than one person."
> *Boston, avid voter who was careful while marking*

## Voters found and fixed errors during marking and review

In our observation notes, we only considered a selection an error if it was an overvote or if the participants noticed and fixed it or if they did not notice it but confirmed that it was a mistake during the debrief after voting. Without this confirmation, we had no way to decide whether they changed their mind or made an error.

Although many participants made errors at some point in the process, they were much more likely to fix them on the BMD.

- **11** voters made an error on their hand-marked ballot, but only one of them fixed it. The other **10** cast a ballot that did not reflect their intent.
- **16** voters made an error on one of the BMDs. **5** were fixed during marking, **6** were fixed from the review screen, leaving only **5** ballots cast that did not reflect voter intent.

**Errors made while marking and how they were resolved**

|  | **Hand-marked** | **System A** | **System B** | **System C** |
|---|---|---|---|---|
| Errors made that we were able to confirm | 11 | 5 | 8 | 3 |
| Fixed during marking | 1 | 4 | 1 | 0 |

|  | Hand-marked | System A | System B | System C |
|---|---|---|---|---|
| Fixed during review | NA | 0 | 4 | 2 |
| Fixed during verify | 0 | 0 | 0 | 0 |
| Didn't fix | 10 | 1 | 3 | 1 |

In some of these cases, participants were aware that they had made an error and decided to accept the difference from their plan. A few simply gave up when they could not figure out how to make a change easily. Some of the willingness to cast a ballot with errors must be attributed to the research context. However, in a few cases, they did not realize there was an error until we asked about it in the debrief.

### They did not expect to have to check the printed ballot

Although a small number of participants were wary of technology and the possibility of *malicious changes,* most were more concerned with *errors.*

A few people commented that they simply didn't expect a printer to not print what was on the screen and felt confident that the ballot would be printed correctly, just like their printer at home. Nothing in their experience of using technology suggested that once they had carefully reviewed the information it would be changed between what they saw on the screen and what came out of the printer.

## Ballot marking device instructions do not encourage verification.

### Voters do not have a strong mental model of the printed ballot as the official ballot to be cast and counted

Participants' understanding of the function of the printed paper ballot included almost every possibility. Less than half of the participants correctly identified that

their votes were cast or recorded when the BMD printed ballot was scanned into the ballot box.

- Others assumed that the electronic ballot interface meant that the votes are recorded on the BMD (or "in the cloud") and the printout was just a backup or a receipt.

- Instructions on the BMD often implied the printed ballot was "final" and told voters to check their ballot carefully *before* printing.

In the discussions with participants, it was clear that without an understanding of the printed paper as *the ballot*, there is little compelling reason to verify it carefully.

More clear instructions on the BMD final screens plus a combination of voter education, signage in the polling place, and the instructions on the ballot could influence voters to verify their printed ballots.

# What design elements encourage review and verification

We began this research with the assumption that the design of a voting system can make a difference in how successful voters are at preventing errors and discovering malicious changes.

The job of a voting system is to support voters to easily select, double-check, and confirm their selections so they can feel confident their ballot is correct. A well-designed voting system helps voters by emphasizing the aspects of voting that need attention at each stage.

This section contains observations by the stage of the voting process, focusing on the aspects of the design that helped voters or were a problem for them.

## Marking the ballot

We used a hand-marked paper ballot designed using the EAC's best practice guidelines, and three BMDs with similar interface designs to try to minimize the variation in the marking stage of the voting process. Although our main goal was to focus on how people reviewed and verified their ballots, the marking phase that comes before it, sets the stage and can affect their behavior throughout the rest of the voting session.

Despite a best-practices hand-marked paper ballot design, we saw people have difficulty filling in the oval (and concentrating on getting it done correctly), one overvote, one person who made an error and asked for a new ballot, some accidentally skipped contests, and many missed opportunities to select more than one on vote-for-N contests.

The marking interfaces of the BMDs all worked similarly, with good presentation of the selections and preventing overvotes. Participants still missed opportunities to fully vote the vote-for-N contests, even with the contests presented one at a time on the screen.

The problems we saw during marking all had an effect on later review and verification.

## Not noticing contests with multiple selections resulted in undervotes

On all three BMDs *and* the hand-marked paper ballot, participants often missed the information when more than one candidate could be selected.

They had a chance to see that the City Council contest allowed three selections when they pre-selected their choices using the voter guide. All of the ballots included an instruction in the contest header to "Vote for Three."

The BMDs all included a progress indicator showing either how many candidates had been selected, or how many more selections could be made.

Despite elements designed to inform voters, all BMDs and the hand-marked ballots resulted in unintentional undervotes in the vote-for-N contests in the marking phase.

## Confusing interactions made changing selections hard

Differences in the BMD interaction designs allowed us to observe the impact of frustration as participants tried to make changes in their selections.

Two of the systems implemented a design based on the Anywhere Ballot, in which even on a vote-for-one contest, voters have to deselect a candidate before choosing another one. While this is consistent in giving voters control over selections, the error messages were confusing and participants struggled to understand them. In one case, a participant gave up and left a contest without making the change they wanted.

In the other system, in a vote-for-one contest, the system just changed to the voter's new choice without any message and this proved more intuitive and less frustrating.

## Difficulty with a touch screen made it hard for participants to feel comfortable using one BMD

All of the participants reported using personal touch-screen devices including smartphone and tablets. One of the BMDs had older touch screen hardware which was not as responsive as more modern devices. This led to problems making selections or activating controls. As a result, many participants had to

work hard to compensate and at least one participant left a screen with the wrong candidate selected. Participants:

- Tapped too lightly or held a tap too long, so the screen did not complete the action.
- Tapped multiple times trying to make a selection, sometimes turning the option on and off.
- Tried different ways of tapping - trying to figure out what was wrong.
- Swiped to scroll down on a BMD that did not support gestures, and accidentally selected a candidate instead.

There may have been a calibration problem, or not enough space around the "See more" button at the bottom of long contests.

The result of this problem was to make the system appear to be untrustworthy.

> "I like the ovals [on the hand-marked ballot] because the screen doesn't always work."

# Reviewing the ballot selections

Only a BMD offers a meaningful review function, confirming that the voter's marks were interpreted as intended and informing them of undervotes (missed opportunities).

Hand-marked paper ballots rely on a voter's understanding and accuracy in the marking stage, so any review is combined with the verification stage.

All of the participants understood that they could make changes from the review screen. However, there were differences in the design of the 3 BMDs that made a difference in how well participants were able to check their selections. This gives us some indications of design elements that help voters find and correct errors from the review screen.

## Announcing the transition to the review screen helps voters switch gears

When voters reached the end of the contests and moved into the review, two design elements helped them realize they were entering a new function: the heading of the review screen and how the transition is made.

Two of the systems included a transitional screen that informed voters that they had seen all of the contests and were switching to the review stage of the process.

The system that did not announce the transition into the review screen also had the most confusing presentation of the information on the review screen. The top of the screen had boxed instructions and the display of the contests and undervote messages had a visual design that made it hard to scan easily. This combination of design problems made it hard for people to engage with the review screen on this system as effectively as on the other BMDs.

> "[This is] hard to read... where should my eye go?"

## Undervote notifications need to be clear and visible ....

The three systems had very different designs for undervote messages, which affected the ability for participants to see undervote notifications and make an effective review.

All three systems displayed contests with no vote with a message saying

> No Selection
> No selection made
> No selection was made for this contest

All of the designs tried find a balance between making the notification visible and not making the message so strong that voters felt compelled to make a selection.

## Designs for showing no selections

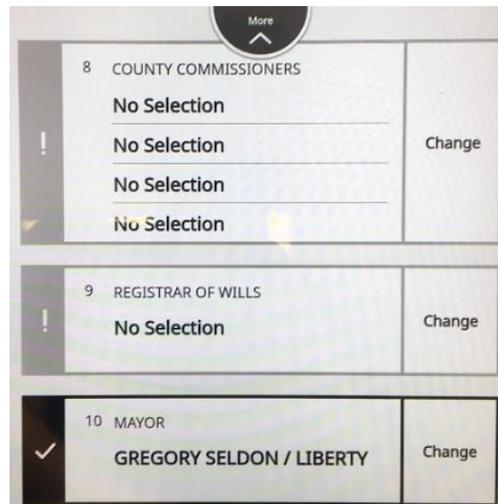| System | Review screen notifications |
|---|---|
| **System A**<br><br>A box below the contest title with a light pink background for undervote notifications.<br><br>For vote-for-n contests, the message reads:<br>"Only 2 of a possible 4 selections were made. Click here to vote." |  |
| **System B**<br>A monochrome color scheme in which voted contests had a dark bar and a checkmark.<br><br>For vote-for-n contests no selections are shown with a grey bar and an exclamation point.<br><br>A partial vote is shown with the black bar and check mark. |  |

| System | Review screen notifications |
|---|---|
| **System C**<br>A warning icon and orange text.<br><br>For vote-for-n contests, the message reads:<br>"2 of 4 selections not made for this contest" |  |

The most successful design was System C's with orange text, which was prominent and easy to see. Participants were more easily able to associate this message with the correct contest than the boxed notification.

Undervotes on a vote-for-N contest were more varied and more difficult to understand.

- System A listed a "no selection" message for each skipped option making it easy to see how many choices were still available.

- System B used the dark bar and checkmark for partially voted contests that was also used for fully voted contests, adding the message "No Selection" for each undervote. Using the same visual design elements for the fully voted and undervoted contests made it harder to see the undervotes. We observed several participants miss the information that they had undervoted.

> A participant using System B saw a message at the top of the screen that said "3 contests with selections not made." They easily found the two blank contests because they looked different, but struggled to find the final missing selection – an undervote in a vote-for-N contest. They gave up on the review screen and instead clicked through every contest until they found the contest with the missing selection.

- System C had a compact presentation with a single line saying, "no selection made for 3 of 4 choices."

  > A participant using System C saw the undervote message, went back to the contest to make a selection, and returned to the review screen…three times (instead of adding the three missing selections all at once)
  > *Baltimore participant with low literacy*

- None of the systems included explicit information about the number of selections allowed, which would provide context for the "no selection" indicators.

## … but not so visible that they feel coercive

In the initial interview, we asked participants about their voting habits, including they last election they voted in, how they prepared to vote, and how they made decisions about whether to vote in a contest or not. Participants were roughly evenly split between those who said that they typically aim to vote on everything on the ballot and those who said they voted only for candidates or questions they cared about.

Some of the participants who made changes from the review screen said that they felt that it was telling them that they *had to* vote on everything possibly because of the style of the message and the language "No selection was made for this contest" and no language saying "You may select up to 3". The stronger and more noticeable the undervote message, the bigger a problem this was.

> "I was supposed to select three. I felt like I had to select three."
> *Participant using System C explaining why they changed a vote from the review screen*

# Printing and casting the ballot

The transition from marking the ballot to printing the ballot is a critical moment. There are challenges because the voter's attention automatically turns towards the printer after pressing print, so any important instructions about verifying and what to do if a problem is found is at risk of being missed. Adding to this problem, is that voters may not have an accurate mental model for when their vote is cast and the role of the printed paper ballot.

## Instructions need to make it clear that the printed ballot can be corrected

All of the BMDs encouraged voters to check their selections on the review screen but inadvertently made it sound like no changes could be made after printing.

The messages often included wording like "last chance" or "final". One BMD did tell voters what to do if they find a problem, but after also stating that you cannot make changes after you print.

**Messages and instructions about the printed ballot**

| BMD | Sequence of message and interactions sequence |
| --- | --- |
| A | Voter taps "Print" at the bottom right of the review screen. |
| | Popup message: "Confirm printing. You are about to print your ballot. Once you proceed you will not be able to make any more changes" |
| | Progress messages: "Preparing ballot for printing" and "Printing Page 1 of 2 Status Printing Ready" |
| | Final message: "Confirm Ballot Printed: When your ballot has finished printing 1 pieces of paper press OK. If there is a problem please contact a poll worker." |

| BMD | Sequence of message and interactions sequence |
|---|---|
| B | Voter taps "Next" at the bottom right of the review screen. |
| | Transition screen: "Ready to print? This is your last chance to go back and make any changes" |
| | Progress screen: "Printing ballot" (with a progress indicator) and "Ballot is printed" |
| | Transition screen: "Ready to cast" with two options: |
| | "Cast your ballot now." and "Read back my printed ballot" |
| C | Voter taps "Next" at the bottom right of the review screen. |
| | Transition screen: "Print your official ballot. If you have reviewed your selections and you are done voting, you are ready to print your official ballot." |
| | Voter taps the "Print" button |
| | Popup message: You may not make any changes after you print your ballot. Do you want to print your ballot?" |
| | Voter taps "Yes, print my ballot" |
| | Transition screen: "Cast your printed ballot. Before you cast your official ballot in the ballot box, double-check your printed ballot to confirm your selections. If you find a mistake, ask a poll worker for help." |

## Mental models of printing assume an "honest" printer

Most people assume that what is printed will match what they see on the screen and that their most important task is to ensure that the selections on the review screen are accurate.

They are worried about *errors* they may have made in marking, and possibly concerned that the printer is working correctly. But unless they are thinking about cybersecurity, nothing in their mental model suggests that the BMD could misprint their ballot.

## The printing process adds complexity to the voting interaction

Whether the BMD has an external or integrated printer, voters have to know to wait for the ballot to print and then what to do with the ballot.

The timing and sequence of instructions on each of the systems made a difference to how successfully voters made the transition from focusing on the screen to focusing on the printed ballot.

Two of the systems use an external printer:

- System A prints a double-sided bubble-style ballot where the printer prints side 1, pulls the paper back in, and then prints side 2. Participants often tried to take the ballot in the middle of the printing process, not realizing it was not done yet.

- System C prints a single-sided list-style ballot, which was easier for participants to retrieve from the printer.

System B has a unique interaction. After the ballot is printed, it is ejected onto a platen so it can be verified. At the voter's signal, it is then drawn back into the printer to be cast. There are messages on the BMD screen to help, but by the time they appeared, participants were no longer looking at the screen as they waited for the ballot to appear.

If the voter picks up the ballot to verify it, they then have to feed it back into the printer to cast it. (This feature also serves an accessibility function, since the system also provides a way to read the ballot back to the voter). Once again, this interaction is at odds with people's mental model of how a printer works. Their instinct is to pick up the printout. Having done so, nothing in their experience matches the idea of putting the ballot back into the printer slot. Even when they noticed and read the instructions on the screen, it simply did not make sense.

> "I couldn't quite figure out why I printed something and then loaded it back into the same thing. Typically, when you print something you are going elsewhere with the thing you printed."

All of these problems can be overcome through thoughtful instructions on the screen, on the printed ballot, and voter education.

The problem this complexity creates for verification is that in the valuable seconds when voters should be checking the paper ballot, their attention is focused on what they should do with paper.

# Verifying the printed ballot

The challenge for verification is to encourage voters to correctly check their ballot for *errors* without reducing trust in the election by over-emphasizing the potential for *malicious changes.*

As we observed participants voting, we saw a range of depth of verification from a simple glance at the ballot to a more detailed reading of the whole thing.

## Verification of hand-marked ballots focused on completeness

Once they completed marking the ballot, many participants took a few seconds for a quick look at both sides, just flipping the ballot over,

A couple of people noticed an undervoted contest and made additional selections to fill in the gap.

In general, however, most participants tended to trust that they had marked the ballot carefully and did not need to further review their selections.

## Verification of BMD-printed ballots was evenly split among participants

Participants using both types of ballots marked them carefully. Using the BMDs, participants followed up with a carefull review on two of the systems before printing.

The critical question for this research, however, is whether they verified their printed ballots before casting. Here the data is evenly split between participants who checked their ballot carefully, checked it with a quick look or did not verify it at all.

One way to read these results is to say that one-third of the voters did not even attempt to verify their BMD-marked ballot.

Another is to say that two-thirds did verify their ballot. These results are in line with prior research at Rice University, in which 25% - 60% of people in their research found malicious changes they made on a review screen of a prototype electronic voting system.

**Care in marking/reviewing selections and verifying the hand-marked/printed ballot**

| | Hand-marked (32) | System A (8) | System B (15) | System C (10) | All BMD (34) |
|---|---|---|---|---|---|
| Careful marking | Yes: 32<br>No: 2 | Yes: 7<br>No: 3 | Yes:13<br>No: 2 | Yes: 9<br>No: 0 | Yes: 29<br>No: 5 |
| Careful on review screen | NA | Yes: 2<br>Some: 1<br>No: 7 | Yes: 9<br>Some: 4<br>No: 2 | Yes: 8<br>Some: 0<br>No: 1 | Yes: 19<br>Some: 5<br>No: 10 |
| Careful hand-marked/printed ballot verification | Yes: 5<br>Some: 11<br>No: 18 | Yes: 5<br>Some: 5<br>No: 0 | Yes: 3<br>Some: 3<br>No: 9 | Yes: 3<br>Some: 2<br>No: 4 | Yes: 11<br>Some: 10<br>No: 13 |

*\* 1 participant is not included because the data was too ambiguous.*

Most mistakes on the BMD, including selecting a different candidate than planned or undervoting, were caught and fixed during marking or review.

None of the participants asked to make a change to their ballot after it was printed.

# What elements support voters with disabilities in verifying their ballot?

We approach our design and research with a universal design philosophy: that making a voting system accessible for voters with disabilities will also make it more usable for other voters. This is because disability can magnify problems. Usability problems that are just small "speed bumps" for most voters, can be high barriers for others.

As an example, small text might be hard for some voters to read, but impossible for those with low vision. On the other hand, the same feature that allows a voter with low vision to magnify the text to 200% or even more, also allows someone with tired or aging eyes to magnify it to 135% to read more comfortably.

In this report, we have included accessibility issues throughout, rather than collecting them separately.

In the bigger picture, however, there are a few important points to consider.

## "Paper just isn't accessible"

This has been a constant refrain in discussions of different types of voting systems. We did not want to bring in participants just to see them be unable to mark their ballot at all. We knew that blind voters and voters with no use of their hands would not be able to use a hand-marked paper ballot.

But we were less sure of the issues with BMDs, so we re-read the Pennsylvania Certification Accessibility Testing reports for insights.

What we read in those reports was that the ability to use the audio-tactile or non-manual controls to successfully mark and review the ballot was largely a function of how usable the accessibility features were. As interesting as it would be, testing the basic marking interface was not part of the scope of this research.

The blind voters in the Pennsylvania testing were interested in being able to verify the printed ballot and some tried using their personal assistive technology to do so. They were not able to read any of the bubble-style ballots independently. They were partially successful with some of the list-style ballots,

and might have been more so with a chance to practice or with information about what reading application settings were most effective.

## List-style ballots can help voters verify them

We started the research with a hypothesis that summary ballots that presented only voter selections (and indicators for when there are no selections) would be easier to read and verify.

### Benefits for voters with cognitive disabilities or low literacy

Like the overall group of participants, people we knew had difficulty reading because of low literacy, vision, or low English proficiency were mixed in their preferences for this style of ballot compared to a bubble-style, and they gave the same reasons as the other participants.

They said having a simpler layout was easier for them.

> "It's more like how you normally read."

On the other hand, participants also reported:

- Confusion about the "no selection" indicator on the ballot, especially if they were no aware that they had undervoted.
- The two-column layout of both of the summary ballots added complexity.

> One participant commented that they had trouble with the fact that there were two columns on their list-style ballots. They weren't sure if the top two items were related and it took a minute to understand that they should read down each column separately.
> *Participant who voted on System C*

Separating the columns can also be a problem for voters using a personal magnifying glass or personal OCR application to verify the ballot. Design solutions include arranging the contests in a single column or putting a separator between the columns.

## Benefits for voters with vision disabilities

Voters with low vision often use magnifiers to read printed material. As they enlarge the text, magnifiers also narrow the area viewed. Reading a list of their selections avoids the risk of missing the marking oval or making a mistake by misunderstanding the relationship between the mark and the name because not enough of the page is in view.

Similarly, blind voters might use personal devices that scan a page and use optical character recognition (OCR) to transform it into text that can be read aloud by a screen reader or other assistive technology.

In the Pennsylvania testing and in our own experimentation with OCR readers, we identified some features of a list-style ballot that would increase their ability to help blind voters verify their ballot independently and privately. All of these design guidelines would also help other voters read the ballot more easily.

- A ballot with a single column, or well-defined regions are easier for these apps to interpret.
- Checkmarks, glyphs, or unnecessary punctuation can confuse the OCR readers.
- Creating full sentences or using visual elements to separate contests is helpful to ensure that as the voter listens to the ballot selections, it is easier to tell which office is associated with which candidate name.
- A simple, sans-serif font is easier to scan.

# Time taken for activities in the voting session

During the voting sessions, we recorded the time spent on the different activities to mark, review and cast a ballot. The timings were captured by a human observer by watching for pre-defined transition moments or actions.

We identified 4 time periods in the voting process, so we could compare times spent on the BMD and hand-marking a ballot.

On each BMD, we identified a consistent voter or system action to use as the transition from one activity to another.

For the hand-marked paper ballot, we identified common user actions to be the triggers for the time-keeper.
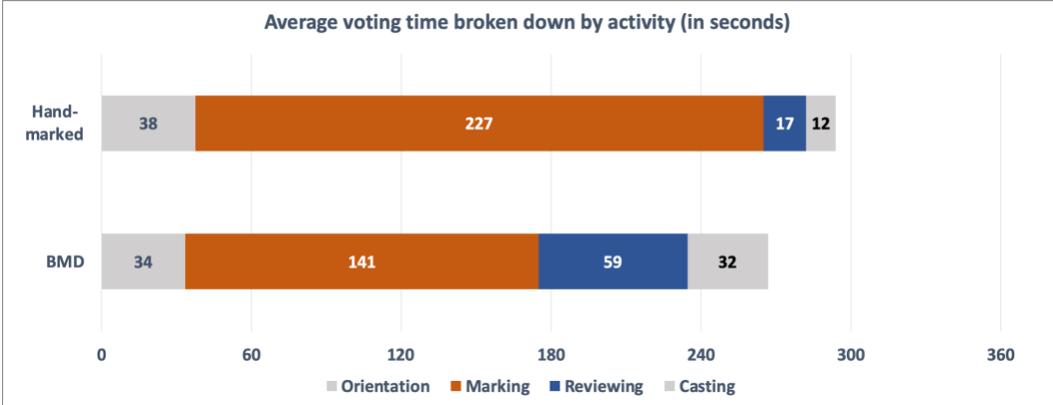
| Activity | Hand-marked paper Activity ends when… | Ballot marking device Activity ends when… |
|---|---|---|
| **Orientation and preparation -** Time from when the participants sat down at the voting station until they began marking the contest | Participant makes their first mark | Participant makes their first mark |
| **Marking the ballot** - Time from the first contest until they completed marking | Participants marks the last contest or puts pen down | System displays the review screen or pre-review screen transition screen |
| **Reviewing the ballot -** Time from the end of marking to when they transitioned into casting. On the BMDs, the review time includes printing time. | Participant stands up to walk to scanner | Participant is presented with the printed ballot |
| **Verifying and Casting** - Time from the end of review until the ballot was cast | Ballot deposited in ballot box | Ballot deposited in ballot box |

# Voting times by activity

Even with the extra time to print the ballot and the additional opportunity to verify the paper ballot, the overall average voting times were almost half a minute faster on the BMD.

The marking and review times were also faster on the BMD, even with the time some participants took to experiment with the interface. For example, a few tried entering write-ins.

The verify and casting times were longer on the BMD, but this data is also affected by the extra time participants took on System B. Almost all of the participants removed the ballot from the printer tray, then had to reinsert it to cast. On the way, several of them also used the accessibility feature of having the system read back the ballot one more time before casting.

**Average voting time broken down by activity (in seconds)**

| | Orientation | Marking | Reviewing | Casting |
|---|---|---|---|---|
| Hand-marked | 38 | 227 | 17 | 12 |
| BMD | 34 | 141 | 59 | 32 |

**Average voting times by activity**

| | Total | Orient | Mark | Review | Verify & Cast |
|---|---|---|---|---|---|
| Hand marked | 294 sec | 38 sec | 227 sec | 17 sec | 12 sec |
| BMD | 266 sec | 34 sec | 141 sec | 59 sec | 32 sec |

# All participants times

We also looked at the times for all individual participants for each voting method. We wanted to see the range from slowest to fastest at voting on a hand-marked ballot and on a BMD.

We were interested in whether there was any pattern in the amount of time someone took in each stage. For example, would someone who spent a long time marking their selections on the BMD take a similarly long time reviewing and verifying. Or would taking more one time in one stage reduce the time in another.

The answer is that there is no simple pattern. There were people who barely glanced at the review screen after taking a long time to mark but a short time on verification, and those who took a more balanced time at each stage.

What is striking is the range of times participants spent on each activity, with outliers—both much slower and much faster than average—in every stage of voting.

Using the hand-marked ballot, with one exception, participants spent almost no time in either a final review or verification, trusting their initial marking to be accurate. The fastest two participants both marked only the three contests they were asked to focus on, but then spent time in the review stage considering the other contests.

Using a BMD, they spent more time using the review screen to check that they had not made any errors, the largest variation in times is based whether they made changes. The reviewing activity included waiting for the printer, but this was similar for all of the BMDs.

For both methods of voting, the challenge for effective verification is getting voters to spend more time on a careful, final check of their ballot before casting.

**Times for all participants showing breakdown by voting activity**

| Time ranges | Times for all participants |
| --- | --- |
| **Hand marked**<br>(rounded to 5 secs)<br><br>Fastest overall time<br>1 minute<br><br>Average time<br>4:55 minutes<br><br>Slowest overall time<br>13:15 minutes |  |

Hand-marked: Total time, broken down by activity, ordered by total time (in seconds)

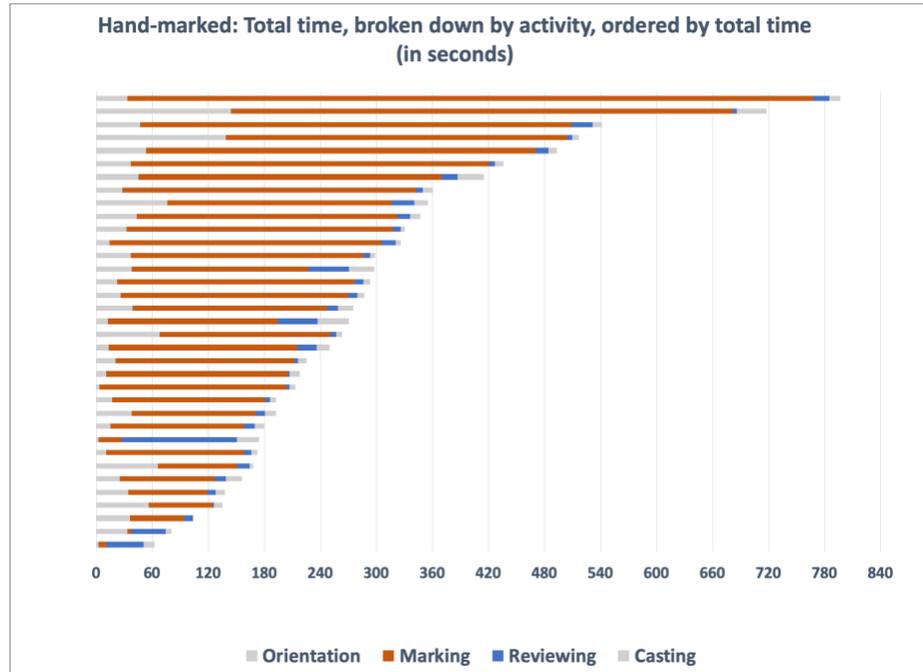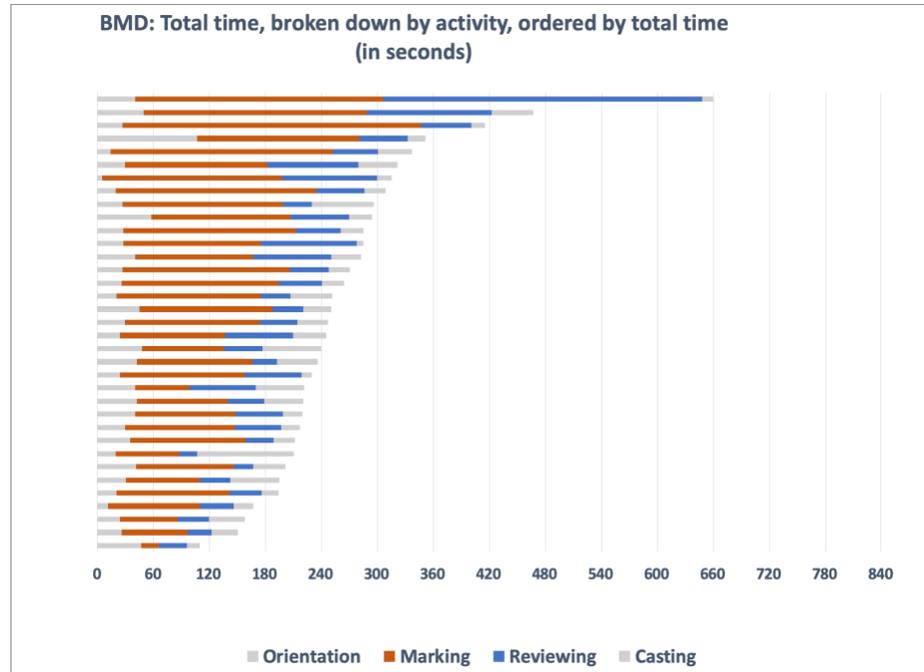■ Orientation ■ Marking ■ Reviewing ■ Casting

| Time ranges | Times for all participants |
|---|---|

**BMD**
(rounded to 5 secs)

Fastest overall time
1:50 minutes

Average time
4:25 minutes

Slowest overall time
11 minutes



BMD: Total time, broken down by activity, ordered by total time (in seconds)

Legend: Orientation, Marking, Reviewing, Casting

# Usability perception

During the interview after marking and casting a ballot, we asked participants to complete a short questionnaire. The System Usability Scale (SUS) is a standard questionnaire used to collect subjective perceptions of the usability of an interactive system in a rapid and light-weight way.

The questions were adjusted for the voting context to make it more directly relevant to voting system usability. Each question is answered on a 5-point scale from Strongly Agree to Strongly Disagree.

Participants completed the SUS after the finished voting on both the hand-marked ballot and the BMD.

The questions are:

1. I am confident that my ballot would be cast as I intended.
2. I understood the process for marking and casting my ballot.
3. The instructions for voting and casting my ballot were easy to follow.
4. I could review my ballot before printing it.
5. It was easy to make corrections to my ballot while I was voting.
6. The printed ballot was easy to read.
7. I was never confused while I was voting.
8. I could verify my ballot before it was cast.

We found little variation in the way participants answered these questions—either comparing one person's assessment of the two ways of voting, or among all of the questionnaires.

The only question in which there was a difference between systems was *#5 – It was easy to make corrections to my ballot while I was voting.* Participants gave a lower rating of "Neutral" to hand-marked ballots and "Strongly Agree" rating for BMDs.

- Three participants left this question blank or wrote NA (not applicable).
- Several asked for an explanation of how a hand-marked ballot could be corrected.

In the discussion of their ratings, it was clear that there was a lot of confusion about whether the hand-marked ballots could be corrected at all and what "verification" means for these ballots.

> I filled it out, so that's verification.

We collected comments from a third of the participants in all three locations saying that there were no instructions about verification or how to make a correction. Some asked what this question even meant for a hand-marked ballot and how making a correction would work.

> I didn't pay attention to corrections. How would I do that?

When told that to make a correction, they would have to get a new ballot, responses were split. Some saw that as an acceptably easy way to make a correction. Others said they would not bother unless the mistake was in a contest they cared strongly about.

> I don't know how to answer the one about making corrections because I wasn't thinking about that. There's nothing there telling me how to change it.

> I'm assuming that if I make a mistake, I can get a fresh ballot.

These comments confirm other findings that people do not understand that neither the printed or hand-counted ballot are *final*, and that they still have a chance to check that their ballot reflects their intent—and make changes if it does not.

# Elections culture in the research locations

The participants at each location came in with slightly different perspectives and expectations.

## Location 1: Boston

In Boston, almost all of the participants had only voted using a hand-marked ballot. Most were comfortable with it because it's familiar, but a couple mentioned that they are curious about the voting machines and saw them as the likely future.

> "I feel like with technology advancements - don't know why we are still doing paper. Everything else is electronic - it would make sense that is where we are trying to go."

Boston participants were also more likely to talk about trust and security– but as a benefit for both methods of voting. One person commented that they liked the BMD better because they trust machines more than people. Another commented that hand-marked ballots are more secure because of all the stories they've heard on the news about hacking.

## Location 2: Los Angeles County

In Los Angeles, where half of the participants last voted with their InkaVote system and the other half with hand-marked ballots, the introductory conversation was much more focused in entertaining all kinds of alternative approaches to voting including electronic voting systems, vote by mail, early voting, and online voting– mainly for reasons of convenience.

> "Now that a lot of things are done online, I would prefer that, just because it is convenient. Getting to the polling place can be difficult because of work even though it is close by."

Many Los Angeles participants also commented about how fun it was to vote using the BMD.

> "I didn't think I would like it but I did… it was almost fun to vote that way"

## Location 3: Baltimore

Baltimore had our largest percentage of participants who had low-literacy levels, vision impairments, cognitive impairments, or limited dexterity. Not surprising, we observed lots of frustration and extra effort required to fill in the hand-marked ballots. One participant who has Multiple Sclerosis especially labored to fill in the ovals because they were using their non-dominant hand, but is the hand that has more function.

# Design principles

When we looked at the problems in each of the stages of the voting process, we realized that basic interaction design principles could be easily applied to the problems we saw, to help people designing voting systems create more usable and accessible voting experiences.

## Confident marking

The interface for marking a ballot is responsible for helping voters make their selections accurately and confidently, with helpful instructions about voting rules and feedback.

**Provides clear feedback.** Selections are recognizable and unambiguous, instructions and error messages helpful and noticeable.

**Prevents selection errors.** Strong connection between a candidate name and the marking position. Prevents accidental selection through gestures, hesitation marks or other voter actions.

**Communicates and enforces voting rules.** Makes the number of options clear. Prevents overvotes in an understandable way.

## Accurate review

The review function helps voters check their selections, emphasizing missed opportunities to vote and confirming their selections.

**Provides a transition.** A message or screen between the final contest and the review screen signals the shift from marking to reviewing

**Separates contests.** The visual presentation connects contest titles, candidate lists and undervote messages, so it is easy to skim through the list of contests.

**Indicates the length of the list.** A prominent display element tells voters when they have reached the end of the list, so they know when they have completed their review.

**Communicates selections clearly.** Candidate or Yes/No answers are easy to read.

**Communicates undervotes clearly.** Messages for undervotes or skipped contests are easy to find and understand.

**Highlights undervotes in a balanced way.** Skipped and undervoted contests are easy to find, but do not feel coercive.

# Transition to print and cast

A successful transition from marking to printing and casting requires that voters learn how to cast their ballot in a way that does not take attention needed for verification.

**Presents instructions at the right time.** Information too early is forgotten, but once the voter's attention shifts to the paper ballot, they miss instructions on the screen.

**Makes the role of the ballot clear.** Instructions emphasize the paper as the official ballot and encourage voters to double-check their votes.

**Makes options during verification clear.** Instructions make it clear that if a voter finds a mistake on the paper ballot, they can alert a poll worker and get a new ballot.

# Verification of printed ballot

Most of the design principles for review also apply to the printed ballot.

**Communicates selections clearly.** Candidate or Yes/No answers are easy to read.

**Communicates undervotes clearly.** Messages for undervotes or skipped contests are easy to find and understand.

**Highlights undervotes in a balanced way.** Skipped and undervoted contests are easy to find, but do not feel coercive.

**Separates contests.** The visual presentation connects contest titles, candidate lists and undervote messages, so it is easy to skim through the list of contests. If

using a multi-column layout, fill the first column first and then move to the top of the next.

**Communicates voting process.** Clearly explains how to cast the ballot and what to do if you discover an error.

**Mockup of a printed ballot with verification instructions:**

# Appendix A: Session outline

The research sessions included marking a ballot using a hand-marked paper ballot and one of three ballot marking devices. After each voting experience, we discussed what happened with the participant and collected their evaluation using a short questionnaire. At the end, we asked them to compare the two experience and the two ballots.

## Initial interview

Each session began with a semi-structured interview to gather information about the participants' voting habits, motivation, and past experiences.

## Preparing to vote

We wanted participants to develop interest and intent in their selections, so we chose asked them to focus on three contests (Governor, City Council, and a question about gambling).

A voter guide had short party platforms and = additional information about those contests. Participants were given the voter guide and time to read it and determine how they wanted to vote on the 3 contests and which parties they preferred.

To help reinforce their intent and voting plan, we asked voters to talk about what caused them to settle on a particular candidate. We encouraged them to write notes in the guide and could bring it with them when they voted.

## Vote using a hand-marked paper ballot

Participants were first given a hand-marked paper ballot and directed to a table with a pen for filling in the bubbles.

When they were done marking their ballot, they crossed the room to the "scanner" (a cardboard box with a slot in the top).  A poll worker was stationed at the table to assist, as is done in real elections.

The debrief included prompts for general reactions and an opportunity for the participant to describe any elements they did or did not find helpful.

This concluded with giving the participant the System Usability Scale (SUS) questionnaire to fill out for to their paper ballot experience.

Before moving onto the next step, we asked the participants to "remind" us of who they had originally picked out during the Voter Guide activity to re-establish their intent.

## Vote using an electronic ballot-marking device (BMD)

For their second voting experience, participants were directed to the BMD to vote. Once again, they could bring their voter guide with them.

After marking, printing and casting their ballot, the debrief included prompts for general reactions, an opportunity for the participant to describe any detail they did or did not find helpful, thoughts on the usability of the printed ballot, and what they understood about when their vote was "officially recorded."

This concluded with giving the participant the System Usability Scale (SUS) questionnaire to fill out with respect to their paper ballot experience.

## Comparing the paper ballots

Once they had voted twice, we asked the participants to compare the two ballots they used.

First, we looked at any differences in how they had voted, whether they were aware of these differences, and why they had changed their voting plan. We did not care why they had made changes, but wanted to understand if they were intentional or accidental.

Then, we looked at the ballot design and asked, "If you were given a choice of how to vote, which would you choose and why."

## Demographics

The session concluded with collecting a small set of demographics questions to allow us to document the range of people included in this research.

# Appendix B: Test materials - Voter guide

Participants were given a voter guide with the names of the parties, candidates, and questions on the ballot and will be instructed to decide who to vote for based on the slogans, and mark it in the guide, as their plan for voting.

The three contests we emphasized in the instructions were positioned throughout the ballot, to encourage participants to look at the whole thing.

**Target contests**

| Contest | Rules | Number of candidates |
| --- | --- | --- |
| Governor | Vote for 1 | 13 candidates |
| City Council | Vote for 3 | 5 candidates in 2 parties |
| Question B: Gambling | Yes or no | Short text (64 words) |

## Page 1 panel

**Franklin County Voter Information Guide**

**General Election**
**Tuesday, November 3, 2020**
Polls are open 7am – 8pm

### What's on your ballot

President/Vice President
US Senate
US Representative
Governor
Secretary of State
State Senator
State Assembly
County Commissioners
Registrar of Wills
Mayor
City Council
Question A: Vehicle Abatement Program
Question B: Gambling
Question C: College District

### Political Parties

There are six parties plus independent candidates represented on this ballot. Each party has submitted official party slogans to help you get a sense of their platforms.

**Federalist Party**
What's good for business is good for all of us.

**People's Party**
Citizens, not politicians.

**Liberty Party**
The voice we deserve.

**Constitution Party**
Running paths in every community.

**Whig Party**
With great power comes great responsibility.

**Labor Party**
Save jobs, cut government.

**Independents**
Varies by candidate

Page 1: List of contests, list of parties represented on the ballot with a short slogan for each (designed to be useful for people who wanted to choose a party to help them decide who to vote for).

## Page 2 panel

**Who is running for office?**

### Governor

The person elected as Governor will be the head of the government for the state of Hamilton. The Governor signs or vetoes bills passed by the state legislature, implements new state laws, appoints state court judges, and can grant pardons to prisoners.

| Candidate | Party | Contact | Slogan |
|---|---|---|---|
| Charlene Franz | Federalist Party — Franzforbiz.biz | | I will use my corporate connections to bring new opportunities to our state. |
| Gerard Harris | People's Party — Garryhearsvoices.org | | I hear all voices. I will hear your voice. Your voice will be my voice. |
| Linda Bargmann | Liberty Party — LibLinda.net | | Teachers should rule. I was one for 25 years and now I'm ready to teach this government how it's done. |
| Barbara Adcock | Constitution Party — Run2walk.org | | Running for a chance to win. But there's nothing better than a good walk. |
| Carrie Steel-Loy | Whig party — SteelFight.org | | Fighting for you. All day and all night. Bring it on. |
| Frederick Sharp | Labor Party — SharpJobs.net | | Good leaders are good servants. Let me serve you and I'll protect your jobs. |
| Alex Wallace | Independent — AlexLovesRose.org | | I want to tax wine. Think of all we could do with that summer Rosé tax money! |
| Barbara Williams | Independent — BarbaraWilliamsforGovernor2020.net | | Laws: bad people don't follow 'em, good people don't need 'em. |
| Althea Sharp | Independent — AltheaSharp123@aol.com | | Tomorrow is looking great. But we need to bring more technology jobs to our town. It's our future. |
| Douglas Alpern | Independent — DougsGovie.net | | Children are our future. Teach them well and let them lead the way. |
| Jelani Bongani | Independent — Jelani2020.org | | It's always darkest before the dawn. |
| Mike Greher | Independent — Greher.net | | I believe in the Tooth Fairy. |
| Patricia Alexander | Independent — AlexanderforGov.net | | I see the goodness in every situation. Good people, good government. |

Page 2: Governor contest: list of candidates, their party, their election URL or email address, and a short slogan.

**Who is running for office?**

## City Council

The people elected to the City Council make laws, set policies, and manage projects to improve the city of Springfield.

→ You may vote for up to 3 people.

| Harvey Eagle | Randall Rupp | Carroll Shry | Beverly Barker | Jin Chen |
|---|---|---|---|---|
| Federalist Party | Federalist Party | Federalist Party | People's Party | People's Party |
| EagleEyeHarvey.org | RandyRupp.win | ShryShry.org | BevBarBar.net | chenFTW.org |
| You Know we're right. Business is where it's at. We need to rezone and build more malls. | I make the hard choices. I do what needs to be done. I'm your guy. | I will lead with integrity, honesty, and commitment. | I have 5,000 Facebook friends. I want to be your friend too. | I represent people, not politics. I want to unite all views. |

Page 3: City council contest: list of candidates, their party, their election URL or email address, and a short slogan.

---

**Ballot Question: B**

# B Gambling

## Ballot question

Shall there be an amendment to the State constitution authorizing Madison and Fromwit Counties to hold referenda on whether to authorize slot machines in existing, licensed pari-mutuel facilities (thoroughbred and harness racing, greyhound racing, and jai alai) that have conducted live racing or games in that county during each of the last two calendar years before effective date of this amendment? Requires implementing legislation.

## What your vote means

| YES | NO |
|---|---|
| A "Yes" vote means that Madison and Fromwit Counties will be able to hold a special election to decide if slot machines can be provided in certain existing gambling establishments. | A "No" vote means that Madison and Fromwit Counties may not hold a special election to decide if slot machines can be provided in certain existing gambling establishments. |

## For and against Measure B

| FOR | AGAINST |
|---|---|
| Adding slot machines will bring in $500,000 of extra revenue and also reduce law enforcement costs in policing these activities now. | We don't need more gambling in our town because it hurts families and degrades our society. |
| **Brian Bachmeyer** Association of Businesses for Gambling | **Marty McAlexanderson** Citizens for a Safe Town |
| **Paula D Johnston** Organizations for Pari-mutuel Slots | **Chuck Pickett** Hamilton Coalition Against Gambling |

Page 4: Ballot question about gambling: ballot language plus supplemental information on organizations that are "for" and "against" that measure.

# Appendix C: Test materials - Ballot

The ballot used in the testing had 14 contests. It includes a range of contest types based on the NIST Medium Complexity Ballot, including "vote for a pair", "vote for 1", "vote for N", judicial retention, and ballot questions.

The candidate names are realistic, but not real.

To avoid using current party names, we selected historical parties, so they are also realistic sounding, but are not current parties. The parties had brief campaign slogans--short but memorable phrases that avoid current political controversies.

**Summary of contests on the ballot**

| Contest type | # | Number of candidates |
|---|---|---|
| Vote-for-a-pair | 1 | 6 pairs of candidates |
| Vote for 1 | 8 | Ranged from 1 to 13 candidates |
| Vote for N | 2 | Vote for 4 with 7 candidates |
| | | Vote for 3 with # candidates |
| Questions | 3 | Yes/No |

Hand-marked ballot, front and back

## Instructions

**Making selections**

Fill in the oval to the left of the name of your choice. You must blacken the oval completely, and do not make any marks outside of the oval. You do not have to vote in every race.

❶ Do not cross out or erase, or your vote may not count. If you make a mistake or a stray mark, ask for a new ballot from the poll workers.

**Turning in the ballot**

Insert the completed ballot into the ballot box to be counted

❶ Do not fold the ballot.

## United States

**President/Vice President**
Vote for 1 pair
- ○ Joseph Barchi and Joseph Hallaren, Federalist Party
- ○ Adam Cramer and Greg Vuocolo, People's Party
- ○ Daniel Court and Amy Blumhardt, Liberty Party
- ○ Alvin Boone and James Lian, Constitution Party
- ○ Ashley Hildebrand and James Garritty, Whig Party
- ○ Martin Patterson and Clay Lariviere, Labor Party

**US Senate**
Vote for 1
- ○ Dennis Weiford, Federalist Party
- ○ Lloyd Garriss, People's Party
- ○ Sylvia Wentworth, Liberty Party
- ○ Heather Nguyen, Constitution Party
- ○ Victor Martinez, Whig Party

**US Representative**
Vote for 1
- ○ Bruce Reeder, People's Party
- ○ Brad Schott, Liberty Party
- ○ Glen Tawney, Constitution Party
- ○ Carroll Forrest, Whig Party

## State of Hamilton

**Governor**
Vote for 1
- ○ Charlene Franz, Federalist Party
- ○ Gerard Harris, People's Party
- ○ Linda Bargmann, Liberty Party
- ○ Barbara Adcock, Constitution Party
- ○ Carrie Steel-Loy, Whig Party
- ○ Frederick Sharp, Labor Party
- ○ Alex Wallace, Independent

**Secretary of State**
Vote for 1
- ○ Barbara Williams, Independent
- ○ Althea Sharp, Independent
- ○ Douglas Alpern, Independent
- ○ Jelani Bongani, Independent
- ○ Mike Greher, Independent
- ○ Patricia Alexander, Independent

**State Senator**
Vote for 1
- ○ Marty Talarico, People's Party
- ○ Laila Shamsi, Federalist Party
- ○ Edward Shiplett, Constitution Party

Remember to vote both sides of the ballot ↓

---

**State Assembly**
Vote for 1
- ○ Andrea Solis, Federalist Party
- ○ Amos Keller, People's Party
- ○ Davitra Rangel, Liberty Party

## County of Franklin

**County Commissioners**
Vote for up to 4
- ○ Camille Argent, Federalist Party
- ○ Chloe Witherspoon, Federalist Party
- ○ Clayton Bainbridge, Federalist Party
- ○ Yasmina Asfour, Federalist Party
- ○ Eric Savoy, People's Party
- ○ Susan Tawa, People's Party
- ○ Mary Tawa, People's Party

**Registrar of Wills**
Vote for 1
- ○ Rhatka Ramachandrani, Independent

## City of Springfield

**Mayor**
Vote for 1
- ○ Orville White, People's Party
- ○ Gregory Seldon, Liberty Party

**City Council**
Vote for up to 3
- ○ Harvey Eagle, Federalist Party
- ○ Randall Rupp, Federalist Party
- ○ Carroll Shry, Federalist Party
- ○ Beverly Barker, People's Party
- ○ Jin Chen, People's Party

## Ballot Questions

**Question A: Abandoned Vehicle Removal**
Vote yes or no

Should the Franklin County Vehicle Abatement Program and vehicle registration fees of one dollar per vehicle be renewed for a ten-year term beginning July 1, 2021, for the abatement and removal of abandoned, wrecked, dismantled, or inoperative vehicles?
- ○ Yes
- ○ No

**Question B: Gambling**
Vote yes or no

Shall there be an amendment to the State constitution authorizing Madison and Fromont Counties to hold referenda on whether to authorize slot machines in existing licensed pari-mutuel facilities (thoroughbred and harness racing, greyhound racing, and jai alai) that have conducted live racing or games in that county during each of the last two calendar years before effective date of this amendment? Requires implementing legislation.
- ○ Yes
- ○ No

**Question C: College District**
Vote yes or no

To upgrade educational facilities and help prepare students for jobs and college transfer by modernizing classrooms and labs, and building facilities for health, medical, science, and technology training, shall the Franklin Community College District issue $450 million of bonds at legal interest rates with independent oversight, audits, and all funds spent on local sites?
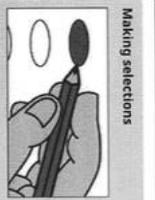- ○ Yes
- ○ No

Remember to vote both sides of the ballot

Machine printed ballot, front and back (Boston)

## Instructions

### Making selections

Fill in the oval to the left of the name of your choice. You must blacken the oval completely, and do not make any marks outside of the oval. You do not have to vote in every race.

Do not cross out or erase, or your vote may not count. If you make a mistake or a stray mark, ask for a new ballot from the poll workers.

### Optional write-in

or write-in:

*Ann*

To add a candidate, fill in the oval to the left of "or write-in" and print the name clearly on the dotted line.
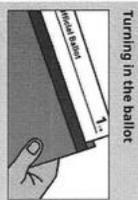
### Turning in the ballot

Insert the completed ballot into the ballot sleeve. Hand in the ballot to be counted.

Do not fold the ballot

Precinct 10 (10) (CS 1)

### President/Vice President
Vote for 1 pair

○ Joseph Barchi and Joseph Hallaren
Federalist Party

○ Adam Cramer and Greg Vuocolo
People's Party

○ Daniel Court and Amy Blumhardt
Liberty Party

○ Alvin Boone and James Lian
Constitution Party

○ Ashley Hildebrand and James Garritty
Whig Party

○ Martin Patterson and Clay Lariviere
Labor Party

○ or write-in

### US Senate
Vote for 1

○ Dennis Welford
Federalist Party

○ Lloyd Garriss
People's Party

○ Sylvia Wentworth
Liberty Party

○ Heather Nguyen
Constitution Party

● Victor Martinez
Whig Party

○ or write-in

### US Representative
Vote for 1

○ Bruce Reeder
People's Party

○ Brad Schott
Liberty Party

○ Glen Tawney
Constitution Party

● Carroll Forrest
Whig Party

○ or write-in

### Governor
Vote for 1

○ Charlene Franz
Federalist Party

○ Gerard Harris
People's Party

○ Linda Bargmann
Liberty Party

○ Barbara Adcock
Constitution Party

● Carrie Steel-Loy
Whig Party

○ Frederick Sharp
Labor Party

○ Alex Wallace
Independent

○ Barbara Williams
Independent

○ Althea Sharp
Independent

○ Douglas Alpern
Independent

○ Jelani Bonqani
Independent

○ Mike Greher
Independent

○ Patricia Alexander
Independent

○ or write-in

Remember to vote both sides of the ballot ↓

---

### Secretary of State
Vote for 1

○ Laila Shamsi
Federalist Party

● Marty Talarico
People's Party

○ or write-in

### Registrar of Wills
Vote for 1

● Rhadka Ramachandrani
Independent

○ or write-in

### State Senator
Vote for 1

● Edward Shiplett
Constitution Party

○ Gregory Seldon
Liberty Party

○ or write-in

### Mayor
Vote for 1

● Orville White
People's Party

○ Gregory Seldon
Liberty Party

○ or write-in

### State Assembly
Vote for 1

○ Andrea Solis
Federalist Party

● Amos Keller
People's Party

○ Davitra Rangel
Liberty Party

○ or write-in

### City Council
Vote for up to 3

○ Randall Rupp
Federalist Party

● Carroll Shry
Federalist Party

○ Beverly Barker
People's Party

● Jin Chen
People's Party

○ Harvey Eagle
Federalist Party

### County Commissioners
Vote for up to 4

○ Camille Argent
Federalist Party

○ Chloe Witherspoon
Federalist Party

○ Clayton Bainbridge
Federalist Party

● Yasmina Asfour
People's Party

● Eric Savoy
People's Party

● Susan Tawa
People's Party

● Mary Tawa
People's Party

○ or write-in

### Question A: Abandoned Vehicle Removal
Vote yes or no

Should the Franklin County Vehicle Abatement Program and vehicle registration fees of one dollar per vehicle be renewed for a ten-year term beginning July 1, 2021, for the abatement and removal of abandoned, wrecked, dismantled, or inoperative vehicles?

○ Yes
○ No

### Question B: Gambling
Vote yes or no

Shall there be an amendment to the State constitution authorizing Madison and Fronwit Counties to hold referenda on whether to authorize slot machines in existing, licensed pari-mutuel facilities (thoroughbred and harness racing, greyhound racing, and jai alai) that have conducted live racing or games in that county during each of the last two calendar years before effective date of this amendment? Requires implementing legislation.

○ Yes
● No

### Question C: College District
Vote yes or no

To upgrade educational facilities and help prepare students for jobs and college transfer by modernizing classrooms and labs, and building facilities for health, medical, science, and technology training, and implementing infrastructure improvements, shall the Franklin Community College District issue $450 million of bonds at legal interest rates with independent oversight, audits, and all funds spent on local sites?

● Yes
○ No

Remember to vote both sides of the ballot ↓

Precinct 10 (10) (CS 1)

Machine printed ballot (LA County)

Machine printed ballot (Baltimore)

**LA County ballot**

Ballot Style 28W00
Serial Number 1
Precinct Number 9990001A

2016
June 7

OFFICIAL BALLOT
Test Election

County of Los Angeles

PRESIDENT AND VICE PRESIDENT
ADAM CRAMER AND GREG VUOCOLO / PEOPLE'S — P

UNITED STATES SENATOR
LLOYD GARRISS / PEOPLE'S — V

UNITED STATES REPRESENTATIVE - 6th District
BRUCE REEDER / PEOPLE'S — Z

GOVERNOR
GERARD HARRIS / PEOPLE'S — 36

SECRETARY OF STATE
MARTY TALARICO / PEOPLE'S — 3J

STATE SENATOR - 31st District
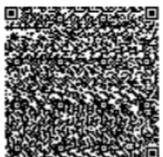PATRICIA ALEXANDER / INDEPENDENT — 3L

STATE ASSEMBLY - 54th District
AMOS KELLER / PEOPLE'S — 3N

COUNTY COMMISSIONERS
CAMILLE ARGENT / FEDERALIST — 3Q
CHLOE WITHERSPOON / FEDERALIST — 3R
SUSAN TAWA / PEOPLE'S — 3U
MARY TAWA / PEOPLE'S — 3V

REGISTRAR OF WILLS
RHADKA RAMACHANDRANI / INDEPENDENT — 3W

MAYOR
ORVILLE WHITE / PEOPLE'S — 3Y

CITY COUNCIL
RANDALL RUPP / FEDERALIST — 43
CARROLL SHRY / FEDERALIST — 44
JIN CHEN / PEOPLE'S — 46

QUESTION A: VEHICLE ABATEMENT PROGRAM
YES on Measure A — 47

QUESTION B: GAMBLING
YES on Measure B — 49

QUESTION C: COLLEGE DISTRICT
YES on Measure C — 4B

**Baltimore / Franklin County ballot**

Ballot Style 12
Precinct Number 23
Serial Number 9BJr3rFLKNEY/ynLvGtGjA

Official Ballot
2020 General Election
Tuesday, November 3, 2020
Franklin County, State of Hamilton

President and Vice-President
Joseph Barchi and Joseph Hallaren / Federalist Party

Senator
Lloyd Garriss / People's Party

US Representative
Brad Schott / Liberty Party

Governor
Alex Wallace / Independent

Secretary of State
Marty Talarico / People's Party

State Senator
Edward Shiplett / Constitution Party

State Assembly
Amos Keller / People's Party

County Commissioners
Eric Savoy / People's Party
Clayton Bainbridge / Federalist Party
Camille Argent / Federalist Party
[no selection for 1 of 4 choices]

Registrar of Wills
Rhadka Ramachandrani / Independent

Mayor
Gregory Seldon / Liberty Party

City Council
Randall Rupp / Federalist Party
Beverly Barker / People's Party
Jin Chen / People's Party

Question A: Abandoned Vehicle Removal
No on Question A

Question B: Gambling
Yes on Question B

Question C: College District
No on Question C

# Appendix D: About the BMDs used for this research

The BMD systems we used were selected because they had useful similarities and differences that could help answer the research questions better than a single system could.

Similarities included the basic interface design, screen size, basic accessibility option, and the use of familiar legal or letter paper sizes for the printed ballot.

The differences included features we thought might be elements that affected the likelihood that participants would verify their ballot, as well as differences in the interface for marking and review.

## System components

What are the physical parts of the system and how are they arranged for voters to use?

| Feature | System A | System B | System C |
| --- | --- | --- | --- |
| **Enclosure** – how is the BMD set up | Components sit on a table<br><br>Tablet on a stand (all ports hidden)<br><br>Tactile controls attached on a cable | Custom voting booth with integrated screen<br><br>Tactile controls integrated, but on a retractable cord | Enclosure sits on a table<br><br>Tablet stand built into enclosure<br><br>Tactile controls built into the base of the enclosure |
| **Printer** – how and where is the ballot printed | Separate COTS printer | Integrated printer | Separate COTS printer |
| **Ballot style** – what does the printed ballot look like | Bubble style ballot | List-style ballot with a QR code on thermal paper | List style ballot on letter-style paper |

| Feature | System A | System B | System C |
|---|---|---|---|
| Product status | VVSG 1.0 certified system in use in several states | In process of certification in California and will be used in Los Angeles County in 2020 | Election Guard is a demonstration system. The VotingWorks software is a part of a product being developed for certification |

## Marking features

On a contest screen, how are the marking and navigation features designed?

| Feature | System A | System B | System C |
|---|---|---|---|
| **Overvotes – vote-for 1** – how does the system implement overvote protection | Selecting a 2nd candidate triggers popup message informs voters to remove current selection first | Selecting a 2nd candidate deselects previous option and changes selection to new choice. | Selecting a 2nd candidate triggers popup message informs voters to remove current selection first |
| **Overvotes – vote-for N** – how does the system implement overvote protection | Selecting N+1 candidate triggers popup message informs voters to remove a current selection first | When N selections are reached, other candidates are dimmed and cannot be selected until 1 is removed | Selecting N+1 candidate triggers popup message informs voters to remove a current selection first |
| **Vote-for-N notification** – how does the system track the number of selections and when all selections are made | Header includes "Vote for #" and a count of selections remaining<br><br>"You have fully voted this contest" | Header includes "Vote for #" and a count of selections remaining<br><br>"Selections left: 0" | Header includes "Vote for #" and a count of number selected.<br><br>"Vote for 4. You have selected 4" |

| Feature | System A | System B | System C |
|---|---|---|---|
| **Navigation in a contest** – does the system require display of all candidates in a contest | No requirement to read the entire contest | No requirement to read the entire contest | No requirement to read the entire contest |
| **See More navigation** - where is the button located | "Touch to see more names" in a yellow button at the top and bottom of the content area.<br><br>No overlap with candidates | "More" in a half-circle button at top and bottom<br><br>Overlaps with top or bottom candidate on the screen | "See More" in a grey button at top and bottom of a blank area on the right<br><br>No overlap with candidates |

# Reviewing features

How are the navigation and display features of the review screen designed?

| Feature | System A | System B | System C |
|---|---|---|---|
| **Navigation to the review screen** – how does a voter reach this screen | Review button on all contest screens goes directly to the review | Review button on all contest screens goes directly to the review | Only by navigating through all contests |
| **Transition** – is there an element that announces the transition from marking to review | No | Yes | Yes |
| **Vote-for-N Notification at top of page –** is there a summary of undervotes on the review screen | No | Number of contests with selections not made | No |
| **Vote-for-N notification – no selections**– how is a contest with no selections signaled | "No selection made. Click here to vote" in pink box under contest title | "No selection"  for each option and box border is gray with "!" to left | "No selection was made for this contest" in orange text with "!" in a circle to the left |
| **Vote-for-N notification - undervoted** – how is a contest with partial selections signaled | "Only # of a possible N selections were made. Click here to vote" in pink box under contest title | Candidate name with "No selection" for undervotes and box border is black with a checkmark to left | "# of N selection not made for this contest" in orange text with "!" in a circle to the left |

| Feature | System A | System B | System C |
|---|---|---|---|
| **Return -** after making a change, how does the voter return to the review screen | Review button at top right<br><br>Next button active in bottom right | "Back to review" button centered at bottom | "Review ballot" button centered at bottom |
| **Return –** position upon return to the review screen | Top of page | Contest just changed | Contest just changed |

# Appendix E: About the Participants

We ran sessions with a total of 35 people in 3 cities:  Boston, Los Angeles, and Baltimore. All were eligible to vote in the United States and currently registered to vote.

| Location | # of participants | Voting system used |
|---|:---:|:---:|
| Boston Public Library | 11 | System A |
| Los Angeles County office | 15 | System B |
| Baltimore University | 9 | System C |

We used Craig's list as our primary outreach, supplemented by social media postings, and used of a list of past participants in Baltimore.

Participants may have been more interested in elections than a random selection, but we worked hard to ensure a range of habits and attitudes. A generous incentive payment of $75 helped ensure that people were well compensated for their time and transportation to the session locations.

## Participant Demographics

We selected participants to end up with a mix of age, education, vocation, and race/ethnicity.

| Characteristic | Range | # | |
|---|---|:---:|---|
| **Age ranges** | 18-21 | 2 | ■■ |
| | 22-24 | 8 | ■■■■■■■■ |
| | 35-60 | 17 | ■■■■■■■■■■■■■■■■■ |
| | 61-70 | 5 | ■■■■■ |
| | 71+ | 3 | ■■■ |

| Characteristic | Range | # | |
|---|---|---|---|
| **Gender** | Male | 14 | ■■■■■■■■■■■■■■ |
| | Female | 21 | ■■■■■■■■■■■■■■■■■■■■■ |
| **Education** | High school | 7 | ■■■■■■■ |
| | Some college | 12 | ■■■■■■■■■■■■ |
| | College | 13 | ■■■■■■■■■■■■■ |
| | Post-grad | 3 | ■■■ |
| **Race/Ethnicity*** | Asian | 3 | ■■■ |
| | Black | 12 | ■■■■■■■■■■■■ |
| | White | 16 | ■■■■■■■■■■■■■■■■ |
| | Latino/Hispanic | 2 | ■■ |
| | Middle Eastern | 1 | ■ |
| **Language used in daily life**** | English only | 26 | ■■■■■■■■■■■■■■■■■■■■■■■■■■ |
| | Spanish | 6 | ■■■■■■ |
| | Others | 7 | Arabic, Farsi, French, Haitian Creole, Hebrew, Japanese |

* Self-identification and may include more than one

** Some spoke more than 1 language in addition to English

## Disabilities

10 participants mentioned at least one physical disability.

6 participants reported limits on activities of daily living.

| Type of disability | Number | Details |
|---|---|---|
| Deafness or severe hearing impairment | 1 | Hearing limited to right ear, but not totally deaf in it |
| Low vision | 2 | Glaucoma in one eye - sometimes easier to read on paper than screen |
| | | No vision in right eye. Left very near-sighted |

| Type of disability | Number | Details |
|---|---|---|
| Limits on physical activities | 7 | Temporary problem with leg |
| | | Birth defect that makes me walk crooked - nothing that keeps me from entering a place |
| | | Difficulty walking, difficulty with shoulder |
| | | Standing for a long period of time, uses a scooter |
| | | Bum right knee.  I can stand and walk but not for long distances |
| | | Multiple Sclerosis (MS) |
| | | Left arm has limited function.  Needs cane to walk |
| Limits on activities of daily living | 6 | Learning, remembering, concentrating (2) |
| | | Dressing, bathing, or getting around inside the home (2) |
| | | Going outside the home alone to shop or visit a doctor's office |
| | | Working at a job or business |
| Reading literacy | 4 | 4 of the participants were recruited from a panel of people who had previously tested for low literacy, with scores of 60 or below on the Rapid Assessment of Adult Literacy in Medicine (REALM) |

For further insights into accessible voting for blind voters and those with limited use of their hands, we drew on published reports from voting system certification accessibility testing in Pennsylvania.

# Appendix F: Participants' voting experience

We asked participants about their past voting experience at the beginning of each session. These questions helped put their actions in marking their ballots into context

| Question | Answer | # | |
|---|---|---|---|
| Last election voted in | 2012 presidential | 1 | ■ |
| | 2016 presidential | 14 | ■■■■■■■■■■■■■■ |
| | 2018 midterm | 10 | ■■■■■■■■■■ |
| | Recent primary, local, or special election | 10 | ■■■■■■■■■■ |
| Last voting location | On election day at a polling place or vote center | 19 | ■■■■■■■■■■■■■■■■■■■ |
| | Before election day at a vote center | 3 | ■■■ |
| | By mail or absentee ballot | 7 | ■■■■■■■ |
| Last voting method | Hand-marked paper ballot | 22 | ■■■■■■■■■■■■■■■■■■■■■■ |
| | InkaVote paper ballot | 8 | ■■■■■■■■ |
| | Touch screen that cast ballot | 4 | ■■■■ |
| | Not sure | 2 | ■■ |

# How much of the ballot they vote on

We also asked the participants to talk about whether they tended to vote on everything on a ballot or focus on just what they're most interested in, and then how they make those decisions.

**How do they decide what contests to vote**

| % | Ballot completeness |
|---|---|
| 40% | Vote everything as informed by research, talking to trusted friends and family, or allegiance to a party |
| 17% | Vote on everything informed by a mix of research, friends, part but also some guesses.<br><br>"Sometimes I just pick something just to finish"<br><br>"If I don't know, I try to guess or make a judgement call." |
| 43% | Vote on the ones they're interested and know about but skip the rest.<br><br>"I'll skip if I don't have an opinion, if it's an issue I care about"<br><br>"I just don't know enough." |

# Motivations for voting

We also asked the participants to talk about what motivates them to vote. Their answers covered many of the broad categories in election research: duty, having a voice, and making changes.

- It can come down to one vote
- Civic duty, fundamental right, responsibility
- Focused on local politics because they matter more
- To be heard / have my say
- People fought for my right to vote, I want to honor that
- My mom/dad wanted me to
- Concerned citizen
- Get better people in government
- Help change things in my local community

- Can't afford not to
- Important, especially now
- If you don't vote, you can't complain
- Chance to come together as a country

# Appendix G: Performance comparison chart

This chart shows a breakdown of how each system performed according to key interaction design principles. It aims to help demonstrate, from a high level, where there are similarities and difference in performance across the three systems tested.

**Performance of error detection and correction by voting system**

Key: ○ = no problems   ◒ = some problems   ● = many problems

| Stage in voting process | Description | System A | System B | System C |
|---|---|---|---|---|
| **Orientation** | | ○ | ○ | ○ |
| **Marking** | Selections clear, Errors noticeable | ○ | ○ | ◒ Active element outline looks like selection |
| | Prevents selection errors | ● Touch delay caused accidental select/ unselects | ○ | ◒ Double tap on next caused skipped contest |
| | Prevents election rules errors | ○ Doesn't allow overvote | ○ Doesn't allow overvote | ○ Doesn't allow overvote |
| | Election rules noticeable & understandable | ◒ Vote-for-N often missed | ◒ Vote-for-N often missed | ◒ Vote-for-N often missed |
| | Errors easily fixed | ◒ Overvote message unclear | ○ Interaction doesn't use overvote message | ◒ Overvote message unclear |
| **Reviewing** | Selections clear, errors noticeable | ● Undervote messages missed or misunderstood | ◒ Undervote messages missed or misunderstood | ◒ Undervote messages noticed but some thought they had to fill in all |

| Stage in voting process | Description | System A | System B | System C |
|---|---|---|---|---|
| | Prevents selection errors | ◒ Accidental click when trying to gesture scroll | ○ | ○ |
| | Election rules noticeable & understandable | ○ | ◒ Confusion with messages at top & inline | ○ |
| | Errors easily fixed | ○ | ○ | ○ |
| | Conduciveness | ● Most didn't interact | ◒ Some didn't interact | ◒ Some didn't interact |
| **Transition to print and cast** | Instructions at point of need | ○ | ● Most missed screen to reinsert ballot | ○ |
| | Process clear | ○ | ● Most tried to walk away without scanning ballot | ○ |
| | Clear that printed ballot could be voided if needed | ◒ ½ didn't | ◒ ½ didn't | ◒ ½ didn't |
| **Printed ballot** | Layout conducive, process clear | ○ | ◒ Hard to read; undervote messages unclear | ◒ Undervote messages unclear |
| | Attempted verification | ◒ Yes=7 Some=4 No=0 | ◒ Yes=3 Some=2 No=9 | ◒ Yes=3 Some=3 No=3 |
| | Mistakes found | ● Discernable mistakes not found | ● Discernable mistakes not found | ● Discernable mistakes not found |

| Stage in voting process | Description | System A | System B | System C |
|---|---|---|---|---|
| **When vote is recorded** | Clear that vote is being recorded when scanned | ◓<br><br>Yes=8<br>No=3 | ◓<br><br>Yes=5<br>No=9<br>Unknown=1 | ◓<br><br>Yes=4<br>No=5 |