Design ideas to improve the usability and security of mail-in ballots

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Despite the renewed discussion on mail-in voting, there has been little evolution on ballot and protocol design for its protocol. This paper describes multiple designs pertaining to ballots, envelopes and chain of custody, that seek to improve the usability, accuracy and security of mail-in ballots. Our proposals include stickers to show voters how many selections can be made and where, and foldable envelopes that allows a user to slide their ballot through a viewing area in an organised way. These proposals also address ways of reducing voting errors for people with reading disabilities, short term memory problems, or motor difficulties.

CCS Concepts: • **Applied computing → Voting / election technologies**; • **Security and privacy → Social aspects of security and privacy**; *Usability in security and privacy*.

Additional Key Words and Phrases: datasets, neural networks, gaze detection, text tagging

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1 INTRODUCTION

With the CoViD-19 pandemic, the usual electoral procedures have been questioned, with elections being postponed or cancelled — such as municipal elections in France or parliamentary ones in Sri Lanka. Where the elections were maintained — such as in Serbia — the health impact has been severe [15]. As it happens, the USA — with its coming presidential election in November 2020 — already has a system in place that could address the issues: mail-in ballots (also known as absentee ballots). Voting by mail, using paper ballots, has multiple advantages in terms of usability and voter safety, but also introduces security issues — which is why it has been decried for decades.

The last two decades of improvements over Direct Record Electronic (DRE) voting machines[1] have shown the importance of design, especially for voters with disabilities (such as visual impairments or tremors [17]), who have a higher number of issues when voting. Although bad user interface design can mislead voters into not succeeding at casting a vote for a given race [1, 21], well-designed systems can reduce the error rate when compared to paper ballots[19]. Moreover, the availability of redundant systems (such as audio interfaces) can make them both more accessible to visually impaired voters, and guarantee the privacy of the latters.

Are there design improvements for paper ballots that could help voters cast votes as intended? This paper is an exercise in translating as many lessons learned from improving ballot success in electronic ballot experiments as possible. Based on earlier studies, the hypothesis is that if paper

[1]Just like mail-in ballots, DREs have been decried for the vulnerabilities they introduce, especially through hacking, but those considerations are beyond the purview of this paper.

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ballots could learn from the structuring and feedback of DRE user experiences, they might also greatly reduce voting errors [19]. while paper doesn't easily have the instant confirmation feedback of a response many of the ideas from electronic voting improvements translated. Lining associated things up, side by side, corroboration of actions with a sticker, clear association, and demarcation, were all helpful. Even Simple tricks such as lining up the votes with a ruler are often used to ameliorate mistakes normally made by people with reading disabilities, short term memory or eyesight problems. This can be improved in some cases with magnifiers as well [2] [4]. This paper takes inspiration from such previous designs and introduces a variety of paper-ballot designs and accessories.

2 OBSERVED ISSUES

This section is devoted to a non-exhaustive analysis of various issues observed in different paper and mail-in ballot systems around the world. The goal is to obtain a partial list of constraints to keep in mind, as improving certain aspects can create new issues. For example, improving security and accuracy often comes with a usability cost. The list of objectives are addressed in the following sections.

2.1 Accuracy and usability problems

Accuracy problems arise in at least two different contexts. First, the voters themselves might make mistakes when filling in their ballot. For example, when faced with long lists of candidates, about 0.4% of the vote go to candidates just above or below well known candidates ballot [20]. They might undervote, also miss a race altogether, or overvote, which can lead to their ballot being voided as they have not selected the correct number of selections for a given race. This can be due to many reasons, but ballot design plays a large role, as was observed in the massive undervote in the Sarasota County, Florida, election[3] in 2004. Similarly, folds in paper ballots can make individual races harder to discern, and could lead to both undervote and overvote. Election officials have often complained about folds fouling ballot feeding in counting machines and optical scanning devices. Selections that are close to a fold can be misinterpreted by the voter and/or durring tallying. Figure **??** shows an election official sorting ballots that had been folded clogged a ballot box in Boston. This can happen where voters choose a single candidate, or a subset of candidates from a list. Accuracy issues seem to be compounded in complex ballots[4]. Ballots where voters are asked to rank or rate candidates as they choose might seem especially complex.

Concerns of finding and marking ballots can be amplified in the context of disabled voters, especially visually or cognitively impaired ones. Many solutions have been devised to improve polling place accessibility, with DREs offering audio controls and audits, or different low-tech solutions for paper ballots [6], such as magnifying set-ups [18]. On that front, increased availability of mail-in ballots has been seen as a mixed blessing by disability activists and security experts as well. Although DREs might lower the cost of voting and give independent private voting for those with disabilities, DRE voting on personal computers or devices has not yet been perfected. Blind voters are entitled to voting independently, and requiring assistance to fill mail-in ballots does not provide access relative to the the ADA law in the USA [11, 12].

[2]For one such example check https://store.inclusionsolutions.com/ballotmag-magnifier-p217.aspx.

[3]A version of ES&S's ballot caused a famous case where 13% of voters missed voting for the second race on the ballot: congressional race 13 in Sarasota, Florida. The race was "hidden" at the top of the second page just above a large headline indicating State races. A race for judge in another Florida county that had a similar "hiding" race had an undervote of more than 21%.

[4]Even in ballots with a single race, many factors can influence voter accuracy: priming effects, layout, confusing or verbose language, or even having many candidates, or some with famous names.

The second context is during the counting of the ballots, multiple recounts often disagree on the exact numbers. This can be due to new ballots being found[5], errors when marking down the results or when announcing them, disagreements over whether certain ballots are spoiled[6].To note, this applies both with Direct Electronic Recording voting machines (DRE) and with paper ballots. Even simple systems with multiple redundancies haven't entirely eliminated counting concerns [5][7]. Scanning ballots also affects this, as the proportion of residuals[8] in the USA typically varies by 0.5% between polling places where voters scan their own ballots and facilities where ballots are centralised and scanned [1, 21].

2.2 Security problems

Another critical issue with voting is their security. Unlike polling places where the ballot custody is contained within a physical space, mail-in ballots present challenges to trusted chains of custody [2]. Having people vote from home exposes the system to two different kinds of risk. First, there is the risk that the wrong ballot or no ballot is sent to the voter. The ballot can be misprinted, delayed during transit or intercepted. These interceptions can lead to multiple negative consequences, most importantly breaching the integrity of the vote by changing the ballot, and breaching the privacy of the voter by finding how they voted. There are multiple ways to address this, and oversight in ballot printing and mailing are essential. Tracking systems through identifiable marks on the ballots or the envelopes could be useful, but care is needed in this so it cannot also be used to breach voter privacy (especially if the people organising the vote are corruptible) [9]. Security and privacy issues are warn against mail-in ballots but , luckily there has been scant evidence of large-scale mail-in ballot fraud [23].

Another non-trivial concern, is the lack of privacy and risk of coercion within one's home. People can be tempted to commit voting fraud by voting for their a family member who is unwilling or unable to. The ability of household members to coerce each other into voting in a particular fashion has been a longstanding problem[9], and while a polling place affords better privacy, coercion is still a possibility, Nursing homes in the USA have also had a reputation for ballots that were identical for large numbers of their residents with voter assistance [7].

[5]The first author has personally witnessed a box of votes were found behind a door in a polling place and had to be airlifted to Los Angeles to be counted in the middle of the night.

[6]This only concerns legitimate disagreements over potentially spoiled ballots, without breaching into the problem of potential fraud in the counting rooms, such as voting officials reviewing ballots in private with access to writing instruments, as the first author witnessed in Wellesley and Arlington MA.

[7]The study cited analyses the French ballot system for presidential elections (in a comparative study with local DREs). It is designed to be simple, with a single race, and instead of putting a check-mark for the candidate of their choice, voters take a piece of paper with the name of the candidate and insert it into an envelope (while in a privacy booth). They then sign the voter rolls as they insert the envelope in the ballot box. Multiple checks at each step also happen with the counting, with the name on each ballot being read out and checked by two officials, under supervision of representatives from the different parties [13]. Despite those redundancies, errors still happen: the study found discrepancies between the number of votes cast and the number of signatures on voter rolls, averaging between 0.08% and 0.32% when using paper ballots, with errors reported in 9.7% of polling offices.

[8]Residual votes correspond to the proportion of overvotes and undervotes for the first race on a ballot.These are often used to analyse effects of technological change.

[9]For example from the early 20th century, the French communists' reluctance to give women the right to vote was linked to fear that they would follow the will of their husband or priest at the polling station, which would add votes for conservative parties [10].

2.3 Goals

We can use and expand the terminology from [16] and apply it to the mail-in ballot problem. Discarding questions of *verifiability*, we focus on their three components of *integrity*, and add a first one, necessary for the others.

Printed and delivered correctly. is the first compound step, and corresponds to making sure ballots are created and delivered correctly. This includes the correction of the following steps: laying out a ballot with appropriate candidates ; having it printed correctly ; having it delivered to the mailing agent with no loss ; having it addressed and then sent without being delayed or lost, either in transit or at delivery.

Cast as intended. is the second step, and corresponds to making sure that the ballot that is sent indeed corresponds to the voter's wish. In this context, it mostly depends on usability. Echoing the earlier issues, this means avoiding unintended residual votes by helping people make selections as intended. It also means making sure that the voter chooses accurately, without the problems mentioned above. Finally, there should also be mechanisms to reduce opportunities for coercion in the home. This paper focuses heavily on this voter usability step as central usability improvement necessary for any ballot to have meaning.

t. he ballot must also be recorded as cast and counted as recorded to be part of the election As an additional consideration is the *legitimacy* of the system. Mail-in ballots have been the subjects of frequent political debates, and fears about the possibility of fraud could be as detrimental as actual fraud, by eliminating the possibility of decision-making and paralysing the political system [8].

3 IDEAS

We here propose a large set of solutions that could be used, to improve different aspects of mail-in voting. We choose to present multiple options as they could lead to improvements in paper ballots and serve further developments.

3.1 Envelope improvements

The second step above might seem to involve only the ballot, but even the envelope can be part of improving filling out the ballot.The envelopes themselves can become usability tools to help voters vote privately, navigate the mail-in ballot, and be more accurate while filling it. Here are three examples of how this could be done.

Focusing mechanisms. To help voters focus on a single race, a sliding ballot holder could be included, as shown on Figure 1, or could be made from the envelope itself. As stated above, lining up a task with a ruler is a commonly taught effective way of helping people with various disabilities reduce their errors. This sliding ballot focuses the voter on the specific options and can serve as a privicay support as well.

As a variation on this solution , part of the envelope could also be either transparent or removable, as is shown on Figure 3. This would be especially helpful when using a single race per fold — as proposed further down. To help visually impaired people, the transparent segment could be a Fresnel lens, as on Figure 2.

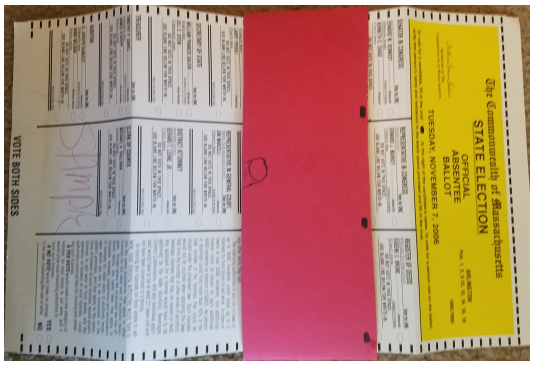

Fig. 1. An example of sliding ballot holder. The voter makes it move along the ballot, and it helps align the races one by one to improve usability and reduce overvote and undervote. This might be especially helpful for people with reading disabilities, tremors, or sight problems.

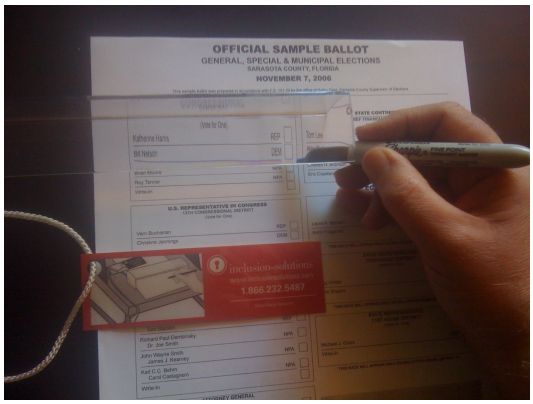

Fig. 2. An example of inexpensive pocket magnifier already proposed for polling places.

Modesty panels. The closing folds of the envelope itself can be used to afford improvement to privacy, by partially concealing the area the voter is focusing on from people in the same room, as is shown on Figure 3.

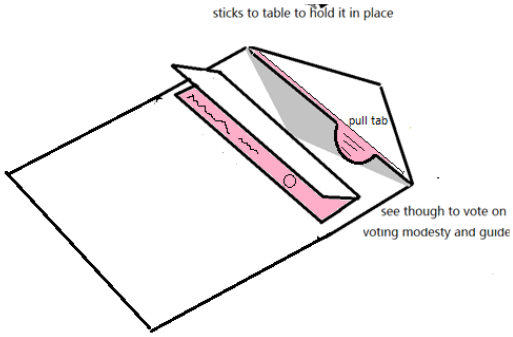

Fig. 3. An example of unfolding envelope. The top unfolds up to partially cover what the voter is looking at.

Sticking envelopes. The bottom of the envelope could be made of removable adhesive. In conjunction with the previous methods, this could increase stability, especially for voters with limited fine motor control.

3.2 Ballot improvements

One race per sheet. So as to reduce accuracy issues and make it simpler for voters, it seems natural to have a single race per sheet of paper. This can be done by having each separate race on a different card (recto only), making the mail-in ballot an envelope containing a stack of cards.This approach is a memory and reading aid that adds a definite action to move from one race to the next

Tabs. Indexing tabs on top of each card could help voters navigate the different races, as shown on Figure **??**. Each card would have a protruding tab, with the summary of the race (like "Presidential" or "Sheriff") indicated on it. As with tabed folders, there could layers of tabs to demarcate different parts of the ballot.

Stickers. Adhesive stickers can give obvious feedback for if a race has been voted. The stickers can be integrated with the ballot, e.g. on the side margins, such that voters unpeel them one at a time, and then stick them in front of the candidate of their choice on the appropriate race 4. This allows the voter to see where and how many selections are available at all times. The feedback of the sticker unused or used helps control for overvoting/undervoting — and to make the mail-in ballot self-sufficient – The stickers should be easy to peel off their initial sheet — a star-like shape for example, has more corners that can be easily peeled up than an oval [10] — without being removable from the ballot without visibly damaging the paper.

The stickers can be laid out on the corresponding tabs, as a memory aid. This way, voters can find out at a glance which races they have yet to vote on. An example of how to add this to a standard ballot is shown on Figure 4. In this case, gutters on each side of the ballot include indications of where races begin and end with stickers associated with each. The gutters were designed to be to pull off as a sticker making changes to the ballot later harder.

[10] Although this creates something akin to gamification which could increase voter engagement,

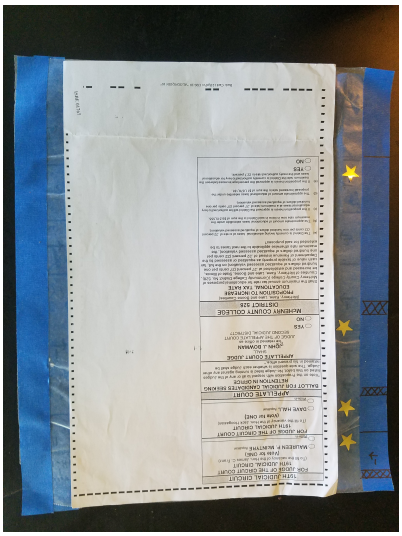

Fig. 4. A ballot with added stickers on the side. The nonstick paper makes it easier to peel them out, and the indicators next to them allow voters to quickly check which races they haven't voted on yet.

A variation of the feedback stickers is to print the ballot on a two layer paper; with the top layer being a sticker that can be removed from the bottom layer. The ballot is printed so that each sticker is printed adjacent to the corresponding race, with as many stickers as allowed selections for that race. The voters peel one off for each race, and sticks it next to the candidate of their choice.

The voter can remove the gutters with unused stickers or put any unused sticker in a designated place at the end of the ballot to ensure that any undervote is intentional[11].

Stickers can be made compatible with write-in candidates a simple example includes leaving two spaces: for the candidate's name, and for the sticker next to it (to ensure that all stickers are used).

Ballot correction mechanisms. Mail-in ballots present the difficulty of getting a replacement ballot if you spoil it. If it is possible to correct mistakes, then a marked ballot might be intercepted and modified. On the other hand, if the decisions made are non-modifiable (for example with unpeelable stickers), any mistake requires the voter to void their ballot, and obtain a new one, might prevent people from voting.

One method is to provide the voter with multiple copies of the blank ballots while preventing them from voting twice. This can be done using tracking systems on the ballots, or a unique and identifiable return envelope, but could confuse voters. A second method is to make ballots initially modifiable, but to add a way to make the ballot non-modifiable once the voter is satisfied. With the If the stickers above are used, a small number of duplicate stickers could be added in tandem with cover-up "undo" stickers that would void whatever sticker was underneath, allowing the voter to put a second sticker on that same race without it counting as an overvote. One approach to this, in the case of a ballot entirely printed on a sticker sheet, is to have a composite sticker that has a couple "undo" stickers within its perimeter; if one or more of these are used, the composite sticker will be missing those. The composite sticker is used to seal the ballot and reveal how many cover-up stickers were used before the ballot was sealed. This makes it clear that the voter put the

[11]This raises the possibility of voiding a ballot by adding more stickers at the end to show that it was doctored, but this is redundant as any adversary who can do that already has access to the ballot.

undo stickers on while voting. a simple approach would includes pasting a transparent sheet onto the ballot to prevent further modifications, as is sometimes done on cheques with sellotape.

More usable ballots for visually impaired people. Braille ballots have been made available in certain places in the USA, but this is not a fully accessible solution, as only some 10% of visually impaired people have the ability to read it, and it could increase error rates in any case [14].

Off-the-shelf applications on phones that can be used to scan the ballot and read aloud what is viewed by the camera could suffice to list the candidates in order (after which the voter could put a sticker on the corresponding dent). Multiple considerations can help secure this approach: multiple alternative transcription applications make none of them a honeypot, all of them could be audited continuously during the vote — including by friends of the voter to check that it works before using it for voting. /begincommentChanging the names or order of candidates would also require non-trivial modifications, as it would only be interesting to do so when certain geographical or political conditions are true (to give a party a statistical advantage). /endcomment

Although reading in braille is not an option for most visually impaired voters, finding a few dents or cuts in the paper should be. By using appropriate markings for the sliding ballot holder, it should then be possible to only show one race at a time. Making an x cut in the ballot to indicate where to put the sticker could improve general usability, while keeping costs low as it could be naturally integrated in the sticker cutting phase. This x can be felt by the voter, and could improve security by making it harder to remove with tearing the paper.

3.3 Chain of custody improvements

Envelope tracking. Making sure that the envelope gets safely from the — legitimate — voter to the ballot box (or the polling office) is the first priority for the chain of custody for the marked ballots. The issue is of course doing that without breaching the voter's privacy.

The simplest case uses our stickers as seal; the composite sticker seal and a signature across the closure flap makes tampering with the ballot evident if the seal is torn. In this case, the closure flap also covers any slide through race viewing slot. The race viewing slot modesty panel is folded down with the envelope closure as well. Another option is to have two return envelopes one inside another. The first envelope bears the name of the voter and is signed by them. Once at the polling office, the officials receive that envelope, check that the voter hasn't voted yet and is on the voter rolls, and then opens it before casting the envelope inside into the ballot box. This is sometimes already done, in one form or another, in certain voting systems, although not always with the security of a second envelope.

To reassure voters that their ballot arrived safely, voters might apply at any point before the vote for a pair of linked scratch-off tickets with unique numbers. They scratch the same digit on both tickets to check that they are indeed identical, and then put one inside their envelope. When the envelopes arrive at the polling office, the ballots are cast in a ballot box, and the tickets in another, to decorrelate them. The tickets are then scratched and checked, and the numbers printed online (or shown at city hall). Inspired by systems already in place in countries like Portugal or Romania [22], the idea is to create an incentive for voters to use the system, by offering some lottery with the tickets (and a special prize if someone shows an inconsistency).

Identifiable ballots. One issue that comes up in recounts is that each subsequent recount finds slightly different totals for each candidate. One method to improve the counting accuracy and eliminate potential avenues for fraud would be to make the ballots identifiable. Not when they are being filled (as it would break the privacy of the voter) but when they are first taken out of the ballot box. A numbering stamp would be enough for the purpose, and make errors easier to track during audits and recounts.

An extension of the post-vote identifiable ballots above is for the person counting the ballots to also be identifiable, for example by having a specific numbering stamp (with a different pattern for each person). This could be useful in hand recounts or in jurisdictions where initial counting is done by hand. Although this could improve the security of the chain of evidence, it also makes it easier to find out who miscounted in which way, which could be used for disciplinary purposes by a powerful adversary in a sufficiently corrupt system.

4 DISCUSSION

The ideas shown here are proposals supported by practices in the disability community and from research on Low Error Voting Interfaces. They each need empirical studies to validate their usability and ease of production and reliability. The CoViD-19 pandemic has made in person studies harder to organise, but at the same time, the potential massive deployment of mail-in voting in the intermediate future also makes those improvements all the more critical, as existing voting protocols might be too impractical not to make changes, even if change seems difficult. As voting officials are often a major part of practical experimentation on such procedures [3], we encourage anyone interested to communicate with the authors for any experimental engagements.

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