Universal-use BMDs undermine election integrity

Today's Electronic Voting Machines: An Examination of the Use and Security of Ballot Marking Devices

Free Speech for People and Coalition for Good Governance

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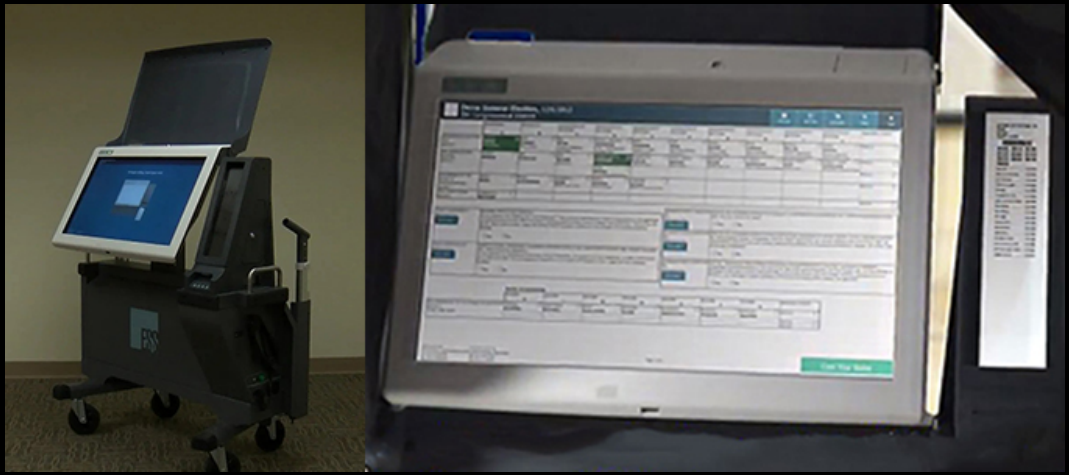
University of California, Berkeley



00000111
ELECTION: GENERAL ELECTION
ELECTION DATE: 11/08/2016
PRECINCT: 740-050 SPG 15 050

U.S. PRESIDENT AND U.S. VICE PRESI-REP DONALD J. TRUMP
U.S. SENATE-----REP SENATOR JOHN BOOZMAN
U.S. CONGRESS DISTRICT 03-REP CONGRESSMAN STEVE WOMACK
STATE REPRESENTATIVE DISTRICT 89 DIS-REP JEFF WILLIAMS
COUNTY JUDGE-----REP JOSEPH K. WOOD
COUNTY ASSESSOR-----REP ASSESSOR RUSSELL HILL
CIRCUIT CLERK-----REP CIRCUIT CLERK KYLE SYLVESTER
CONSTABLE DISTRICT 01 DISTRI-REP CONSTABLE JOHN DUGGAR
MAYOR SPRINGDALE-----MAYOR DOUG SPROUSE
CLERK/TREASURER SPRINGDALE-----NO SELECTION MADE
ALDERMAN WARD 1 POSITION 2 SPRINGDALE-----ERIC FORD
ALDERMAN WARD 2 POSITION 2 SPRINGDALE-----RAY DOTSON
ALDERMAN WARD 3 POSITION 2 SPRINGDALE-----JEFF WATSON
ALDERMAN WARD 4 POSITION 2 SPRINGDALE-----JEREMY LYNCH
ISSUE NO. 1-----FOR ISSUE NO 1
ISSUE NO. 2-----FOR ISSUE NO 2
ISSUE NO. 3-----NO SELECTION MADE
ISSUE NO. 4-----FOR ISSUE NO 4
ISSUE NO. 5-----FOR ISSUE NO 5
ISSUE NO. 6-----FOR ISSUE NO 6
ISSUE NO. 7-----FOR ISSUE NO 7
UNOPPOSED CANDIDATES-----NO SELECTION MADE

IMAGECAST® X | BMD

Ballot Marking Device that prints a paper ballot after a voter marks their selections using the touchscreen.

The ImageCast® X can be configured as a Ballot Marking Device (BMD), which is paired with a commercially available, compact laser printer that prints a summary of the voters selections. No votes are stored on the ImageCast® X when in the BMD configuration.

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DEMONSTRATION BALLOT

VSAP Demonstration Election

VSAP
Voting Solutions for All People

County of Los Angeles

Claimed benefits of BMDs

- prevent overvotes
- warn of undervotes
- eliminate ambiguous marks

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Assume BMDs function correctly!

Many recent failures, including Georgia, Northampton PA, Los Angeles CA

Claims

- voters also make mistakes marking HMPB, so have to verify regardless: not different
- it's enough if X% of voters verify
- if there are complaints/problems, election officials will "do the right thing"
- parallel testing is possible in principle, so all's well

Reality

Hand-marked paper ballots are a record of what voters did.

BMD printout is a record of what machines did.

BMDs make the paper trail hackable: undermine audits & evidence-based elections

- Voter responsible for cybersecurity, but can't prove to anyone else they observed a malfunction: not *contestable*
- Election official can't tell whether a complaint shows malfunction, voter error, or "wolf": no good dispute resolution
- Election official can't prove outcomes are right: not *defensible*
- Full hand count of BMD printout might not show who really won
- Applying RLA procedure to BMD printout doesn't limit risk of certifying wrong winner

Can Voters Detect Malicious Manipulation of Ballot Marking Devices?

Matthew Bernhard, Allison McDonald, Henry Meng, Jensen Hwa, Nakul Bajaj*, Kevin Chang, J. Alex Halderman

University of Michigan *The Harker School

***Abstract*—Ballot marking devices (BMDs) allow voters to select candidates on a computer kiosk, which prints a paper ballot that the voter can review before inserting it into a scanner to be tabulated. Unlike paperless voting machines, BMDs provide voters an opportunity to verify an auditable physical record of their choices, and a growing number of U.S. jurisdictions are adopting them for all voters. However, the security of BMDs depends on how reliably voters notice and correct any adversarially induced errors on their printed ballots. In order to measure voters' error detection abilities, we conducted a large study (N = 241) in a realistic polling place setting using real voting machines that we modified to introduce an error into each printout. Without intervention, only 40% of participants reviewed their printed ballots at all, and only 6.6% told a poll worker something was wrong. We also find that carefully designed interventions can improve verification performance. Verbally instructing voters to review the printouts and providing a written slate of candidates for whom to vote both significantly increased review and reporting rates—although the improvements may not be large enough to provide strong security in close elections, especially when BMDs are used by all voters. Based on these findings, we make several evidence-based recommendations to help better defend BMD-based elections.**

However, BMDs do not eliminate the risk of vote-stealing attacks. Malware could infect the ballot scanners and change the electronic tallies—although this could be detected by rigorously auditing the paper ballots [50]—or it could infect the BMDs themselves and alter what gets printed on the ballots. This latter variety of cheating cannot be detected by a post-election audit, since the paper trail itself would be wrong, and it cannot be ruled out by pre-election or parallel testing [51]. Instead, BMD security relies on voters themselves detecting such an attack. This type of human-in-the-loop security is necessary in many systems where detection and prevention of security hazards cannot be automated [18]. However, as several commentators have recently pointed out [7], [20], [51], its effectiveness in the context of BMDs has not been established.

Whether such a misprinting attack would succeed without detection is highly sensitive to how well voters verify their printed ballots. Every voter who notices that their ballot is misprinted and asks to correct it *both* adds to the evidence that there is a problem *and* requires the attacker to change an additional ballot in order to overcome the margin of victory

Fig. 3: *Warning Signage.* One of the interventions we tested was placing a sign above the scanner that instructed voters to verify their ballots. Signage was not an effective intervention.

Experiment	*N*	Were observed examining ballot	Reported error on exit survey	Reported error to poll worker
Without interventions:				
E1: Regular ballots	31	41.9%	6.5%	6.5%
E2: Summary ballots	31	32.3%	6.5%	6.5%
E3: Deselection only	29	44.8%	10.3%	6.9%
Subtotal/Mean	91	39.7%	7.8%	6.6%
With interventions:				
E4: Signage	30	13.3%	3.3%	6.7%
E5: Script variant 1	30	46.7%	13.3%	6.7%
E6: Script variant 2	25	92.0%	16.0%	16.0%
E7: Script variant 3	31	38.7%	19.4%	12.9%
E8: Slate with script variant 2	13	100.0%	38.5%	38.5%
E9: Slate with script variant 3	21	95.2%	71.4%	85.7%
Subtotal/Mean	150	64.3%	24.0%	27.8%

Voter Verification of BMD Ballots Is a Two-Part Question: Can They? Mostly, They Can. Do They? Mostly, They Don't

Philip Kortum, Michael D. Byrne, and Julie Whitmore

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ABSTRACT

The question of whether or not voters actually verify ballots produced by ballot marking devices (BMDs) is presently the subject of some controversy. Recent studies (e.g., Bernhard, et al. 2020) suggest the verification rate is low. What is not clear from previous research is whether this is more a result of voters being unable to do so accurately or whether this is because voters simply choose not to attempt verification in the first place. In order to understand this problem, we conducted an experiment in which 108 participants participated in a mock election where the BMD displayed the voters' true choices, but then changed a subset of those choices on the printed ballot. The design of the printed ballot, the length of the ballot, the number of changes that were made to the ballot, the location of those changes, and the instructions provided to the voters were manipulated as part of the experiment. Results indicated that of those voters who chose to examine the printed ballot, 76% detected anomalies, indicating that voters *can* reliably detect errors on their ballot if they will simply review it. This suggests that administrative remedies, rather than attempts to alter fundamental human perceptual capabilities, could be employed to encourage voters to check their ballots, which could prove as an effective countermeasure.

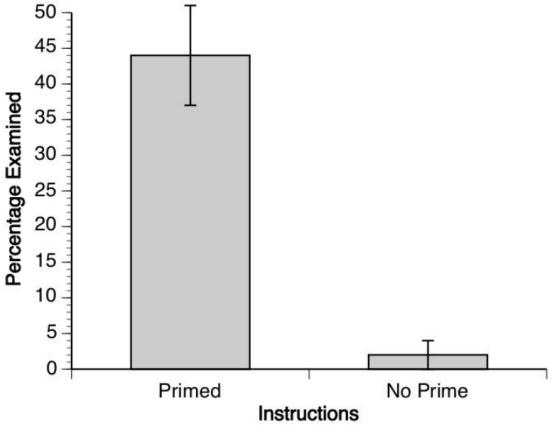

Figure 4. Percentage of voters who examined their ballot as a function of whether or not they were primed to do so by instructions and the poll worker. Error bars represent one standard error of the mean.

Can we show that BMDs didn't change any outcomes?

- 3 approaches proposed:
  - pre-election logic and accuracy (L&A) testing
  - "passive" testing
  - "live" or "parallel" testing
- none works in practice
  - need a big chance of finding small problems in high-dimensional space
  - requires prohibitively large samples
  - most jurisdictions don't have that many voters!
  - none actually does such testing

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- Altering votes on 1% of transactions can change the margin of contests that are not jurisdiction-wide by far more than 2%.

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- Altering votes on 1% of transactions can change the margin of contests that are not jurisdiction-wide by far more than 2%.
- If a contest is on 10% of ballots & undervote rate in the contest is 30%, altering votes on 1% of transactions can change margin in that particular contest by 29%.

Passive testing

- use spoiled ballot rate or complaints to signal a possible problem
- need to set alarm threshold to balance false alarms and missed problems
- may depend on things that vary from election to election:
  - number of contests on the ballot
  - whether the contests have complex voting rules
  - ballot layout
  - voter demographics
  - turnout
  - familiarity w voting technology
  - . . .

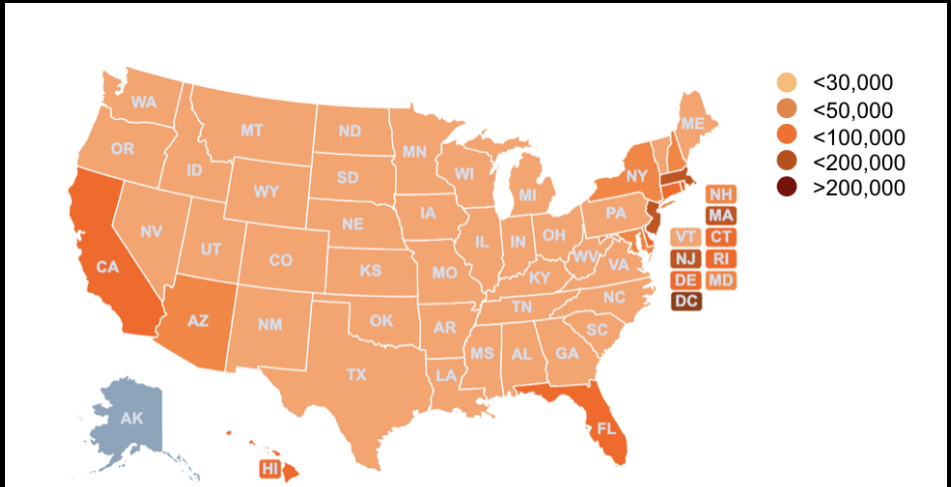
1% false negative & false positive rate, Poisson

margin	detection rate	0.5% base rate	1% base rate	1.5% base rate
1%	7%	908,590	1,792,330	2,675,912
	25%	76,077	145,501	214,845
3%	7%	106,411	204,651	302,864
	25%	9,870	17,674	25,359
5%	7%	40,156	75,671	110,989
	25%	4,036	6,849	9,650

Size matters: contests can have dozens to millions of voters.

median turnout in 2018 was 2,980 voters per county.

$<$ 43,000 voters for $>$ 2/3 of jurisdictions



Targeted attacks

- voters not equally likely to detect discrepancies
- malware has access to BMD settings, state history, etc.
- can select whose votes to alter, inferring voter characteristics from BMD settings and the voters' interaction with the BMD.
- can target voters less likely to notice problems (&perhaps less likely to be believed if they report malfunctions)

Voters with visual impairments

- ~0.8% of the U.S. population is legally blind; approximately 2% of Americans age 16 to 64 have a visual impairment.
- Current BMDs do not provide voters with visual impairments a way to check whether the printout matches their selections
- If 2% of voters have a visual impairment that prevents them from checking the printout and BMD only alters votes when the voter uses the audio interface or large fonts, BMD might be able to change the outcomes of contests with jurisdiction-wide margins of 4% or more wo increasing the spoiled ballot rate.

Voters with motor impairments

- Some BMDs let voters print & cast a ballot without looking at it, e.g. ES&S ExpressVote® with "Autocast,"
- Voters who use this feature have no opportunity to check whether the printout matches their selections nor to spoil the ballot if there is a discrepancy.
- BMD can change every vote cast using this feature without increasing the spoiled ballot rate.

Voters who use languages other than English

- Federal law requires some jurisdictions to provide ballots in languages other than English.
- In 2013, ~26% of voters in Los Angeles County spoke a language other than English at home
- If many voters use foreign-language ballots & are unlikely to check the English-language printout, could change the outcome of contests w/ large margins without increasing the spoiled ballot rate noticeably.

“Learning” voter behavior

- time of day the transaction starts
- the time since the previous voter finished using the BMD (a measure of how busy the polling place is)
- the number of voting transactions before the current transaction
- the voter’s sequence of selections in each contest, including undervotes, before going to the next selection
- the number of times the voter changes selections in each contest in the first pass through the ballot, and what the voter changed the selection from and to, etc.
- the amount of time the voter takes to make each selection before taking another action (e.g., going to the next contest)
- whether the voter looks every page of candidates in a contest

- how much time (if any) the voter takes to review selections, which selections the voter changes, etc.
- whether the voter receives an inactivity warning during voting
- what part of each onscreen voting target the voter touches
- BMD settings, including font size, language, whether the audio interface is used, volume setting, tempo setting, whether voter pauses the audio, whether voter "rewinds," and whether the voter uses audio only or synchronized audio/video
- whether voter uses sip-and-puff interface

Conservatively 6,000,000 to 10^47 combinations.

Spying on voters

Number of voters that have to be spied on *in a given contest* to get 99% confidence from 2000 tests

Altered Votes	Bound (millions)
0.5%	3.87
1%	3.58
3%	2.69
5%	2.09

Limiting BMD use helps: GA Attorney General Contest, 2018

Official results:

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CHRIS CARR (I) (REP) 51.30%  1,981,563
CHARLIE BAILEY (DEM) 48.70%  1,880,807
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margin: 2.6%
ballots cast: 3,949,905
votes cast in Fulton County: 415,524

voting method	detection rate[1]	hack rate[2]	do-over rate[3]	Fulton share[4]
all BMD	6.6%	0.014	<0.001	374
	20%	0.016	0.003	1325
	76%	0.053	0.040	16,782
50% BMD	6.6%	0.027	0.002	374
	20%	0.032	0.006	1325
	76%	0.106	0.081	16,782
5% BMD	6.6%	0.273	0.018	374
	20%	0.319	0.064	1325
	76%	1	0.808	16,782

[1]Rate at which voters who use BMDs notice printout errors and request a new chance to mark a ballot.
[2]Error rate in BMD printouts sufficient to change the reported winner.
[3]Among voters who use BMDs, the fraction who request a fresh chance to mark a ballot.
[4]If the errors were spread evenly across counties, the number of do-over requests in Fulton County.

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- BMDs will always pose special risks of disenfranchising some groups of voters