Usability of Code Voting Modalities

Karola Marky, Martin Schmitz, Felix Lange and Max Mühlhäuser
Technische Universität Darmstadt
Darmstadt, Germany
{marky, schmitz, lange, max}@tk.tu-darmstadt.de

ABSTRACT

Internet voting has promising benefits, such as cost reduction, but it also introduces drawbacks: the computer, that is used for voting, learns the voter's choice. Code voting aims to protect the voter's choice by the introduction of voting codes that are listed on paper. To cast a vote, the voters need to provide the voting code belonging to their choice. The additional step influences the usability. We investigate three modalities for entering voting codes: manual, QR-codes and tangibles. The results show that QR-codes offer the best usability while tangibles are perceived as the most novel and fun.

CCS CONCEPTS

• **Security and privacy** → **Usability in security and privacy**;

KEYWORDS

E-Voting; Code Voting; Tangibles; Usability Evaluation.

INTRODUCTION AND BACKGROUND

Internet voting offers promising benefits such as an improved accessibility, cost reduction and vote casting from any venue having Internet access. But it also involves vote privacy drawbacks: since an electronic device is used for voting, this device learns the voters' choices and thus could transmit them unwantedly to a third party.

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Code Voting [10] addresses this drawback by protecting the voters' choices. Instead of entering the choices directly, the voters enter *voting codes* that represent their choices. The voting device does not have knowledge about the relations of the voting codes and the corresponding choices, because they are listed on a separate *code sheet* that is distributed prior to the election.

In order to cast a vote, the voters need to locate their preferred choices on the code sheet and enter the corresponding voting codes into the voting device. The introduction of code voting enhances the security and influences the usability of the e-voting scheme, because it introduces additional steps into the vote casting process.

While most code voting protocols are based on the usage of manual codes or do not specify how the voters enter or transmit the voting codes, there are different possibilities to do so. First, the voters could manually enter the voting codes. QR-codes gained popularity in many areas and are used in existing e-voting systems to transfer data either from paper to a device [3] or between devices [5, 6]. In a study of vote verification in which two manual transfer methods are compared to QR-codes, QR-codes are recommended for deployment [8]. Therefore, QR-codes could be used in the code voting setting for entering the voting codes. Alternatively, physical tangible objects may offer a more direct and intuitive vote casting process by encoding the voting code in their internal structure. That is, the voters could choose the voting tangibles of their choices and place them on an interactive surface to cast a vote.

In this paper, we explore the usability of three code voting modalities that could be used for voting code interaction:

(1) Manual codes
(2) QR-codes
(3) Tangibles

We report a comparative evaluation with 18 participants in within-subject design. We conclude that QR-codes are suited well for code voting, because they offer the best subjective usability. Tangibles should be used of for special voter groups, such as blind people, because they offer a good usability, but their effort is currently too high for a large scale deployment.

CODE VOTING MODALITIES

In Internet voting, voters use their own devices for vote casting and due to the massive distribution of malware, malware on these devices cannot be ruled out. In most schemes (cf. [4, 6]) the voters' choices are entered in clear into the voting device, which gains knowledge about those choices. In code voting [10], the voters' choices are linked to voting codes. The following input modalities can be used in any code voting scheme. For the sake of the user study, we use the well established protocol *Pretty Good Democracy* (PGD) [10] as a basis.

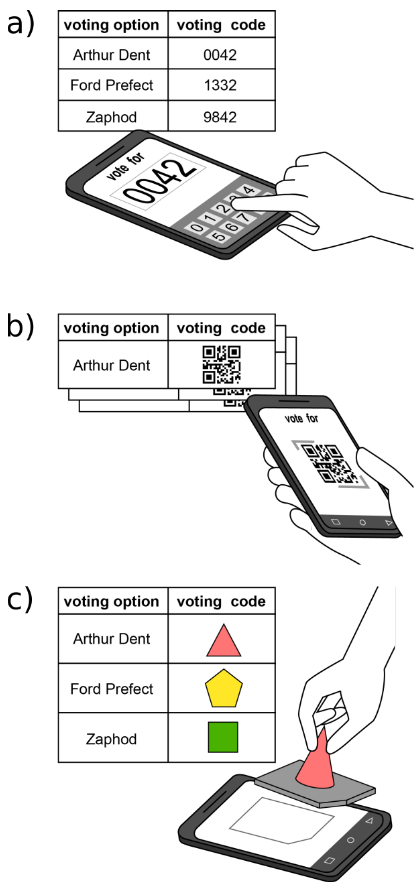

Figure 1: Code voting modalities: a) manual, b) QR-codes and c) tangibles.

Manual

This modality directly follows the PGD protocol. The voters authenticate themselves in the voting client, in our user study we chose a voter-ID and a password that are distributed with the code sheet. After authentication, the voters have to enter their code sheet's serial numbers. This is required for matching the voting code to a voting option in the tally. Then, the voters enter the voting code that matches their choice and confirm the choice in the next step (see Figure 1a). Finally, the vote is submitted to the electronic ballot box. The electronic ballot box answers with an acknowledgement code that is listed on the code sheet to confirm a successful vote storage.

QR-Codes

A QR-code is a machine readable two-dimensional code, that can encode different data types. For the decoding of QR-codes, commercially available smartphones with decoding apps can be used. To realize PGD with QR-codes, two types of QR-codes are required: serial number QR-codes and voting QR-codes. After authentication, the voter scans the QR-code encoding the code sheet's serial number. Then the voter proceeds by scanning the QR-code that encodes the vote code of her or his preferred voting option (see Figure 1b). The following steps do not differ from PGD. Thus, the only difference from the manual modality is that the serial number and the vote codes are represented by QR-codes.

Tangibles

Tangibles are physical objects used to interact with digital information. Commonplace capacitive touchscreens can detect the identity and location of a tangible [2, 9]. As this detection works with passive objects, which do not contain any active electronics and also can be easily and individually fabricated [11], tangibles might be well suited as means to perform PGD. Two kinds of tangibles may be used: serial number tangibles and multiple voting tangibles. After authentication, the voter places the serial number item on the capacitive touchscreen and the software decodes the embedded serial number. Next, the voter chooses the voting item that corresponds to his or her preferred choice and places it on the capacitive touchscreen (see Figure 1c). The following steps do not differ from PGD.

EVALUATION

To investigate the usability of the three code voting modalities, we conducted a user study with 18 participants. To evaluate the usability, we rely on the System Usability Scale (SUS) [1] and the User Experience (UEQ) [7] questionnaire. For our study, we implemented an Android application for each modality and populated them with texts and ballots matching the direct candidate race of the last election for the German Federal Government. The race had six contesting candidates.

Figure 2: Manual modality in the user study.

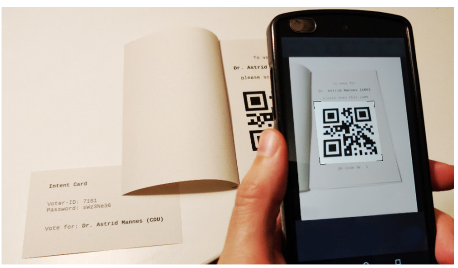

Figure 3: QR-codes in the user study.

Figure 4: Tangibles in the user study. The red tangible shows the 3D-printed encoding on the bottom.

In the manual modality (see Figure 2) we provided a code sheet with 8-digit voting codes. For the QR-code modality, we provided a code sheet book with the QR-codes on separate pages to mitigate an accidental scan of the wrong candidate (see Figure 3). For the tangibles modality, we used 3D-printed tangibles that encode the candidate by embedded capacitive filaments [11]. A depiction of the tangibles and the intent card in the study is given by Figure 4.

Participants and Procedure

We recruited 18 participants by mailing lists, posters, flyers and word-of-mouth. Our participants were on average 30 years old ($Median = 26.5$, $Min = 18$, $Max = 62$, $SD = 9.8$) and six identified as female. All participants use smartphones on a regular basis, and 15 have an academic background.

The participants were invited to our lab, and we did not reimburse them. Our study's procedure was as follows: first, we explained the procedure of the study and asked the participants to sign a consent form. Then, they completed a demographics questionnaire. We proceeded by explaining the intent card which tells the participant which candidate to vote for because we intended to preserve the participants' vote privacy. Then we handled the smartphone. The participants interacted with each modality one after another. When they reported completion, the examiner handled the SUS and UEQ questionnaires. Having completed those, the examiner handled the next modality until the participants had interacted with each of the three. We counterbalanced the order of the modalities according to the Balanced Latin Square. The participants received a final questionnaire asking which modality they preferred and why and for additional feedback/remarks. Finally, the participant was debriefed.

Results

All participants were able to successfully cast a vote in each modality. The manual modality received a mean SUS score of 61.25 ($Min = 27.5$, $Max = 87.5$, $SD = 16.63$), the QR-codes received 84.02 ($Min = 55.0$, $Max = 97.5$, $SD = 11.05$) and the tangibles received 78.61 ($Min = 42.5$, $Max = 100.0$, $SD = 15.49$) points. Figure 5 depicts the SUS scores. A repeated measures ANOVA of the SUS scores reveals significant differences between the three modalities ($F(2, 34) = 18.028$, $p < .001$). Post-hoc tests, using pairwise comparisons and Bonferroni correction, reveal a significant difference between manual and QR-codes ($p < .001$) as well as manual and tangibles ($p = .004$).

The UEQ assesses the six *UEQ scales* of *attractiveness*, *perspicuity*, *efficiency*, *dependability*, *stimulation* and *novelty*, each in a range from -3 ("horribly bad") to +3 ("extremely good"). Figure 6 depicts the mean UEQ scales for the three modalities. The manual modality's novelty is -1.15 and was evaluated negatively according to [7]. The perspicuity of 0.90 means a positive evaluation while all other scales indicate a neutral evaluation, because the values are between -0.8 and 0.8. The QR-codes received a positive evaluation in the scales attractiveness, perspicuity, efficiency and dependability and a neutral

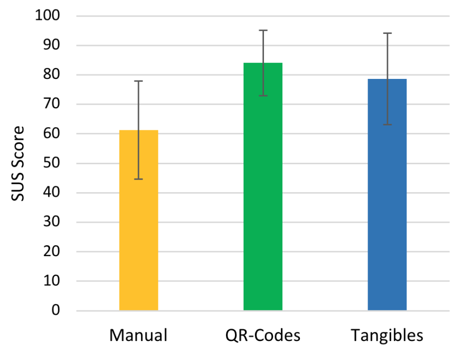

Figure 5: SUS scores

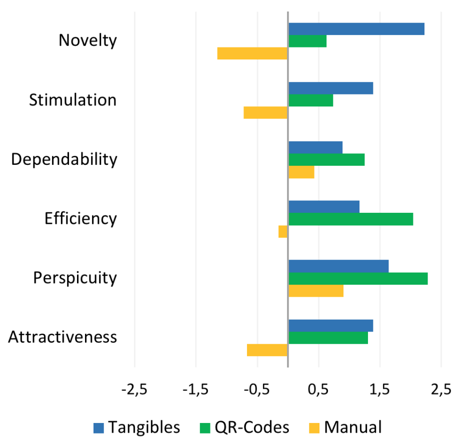

Figure 6: UEQ Scales

evaluation regarding stimulation and novelty. The tangibles received values that are higher than 0.8 in each scale, meaning that each scale represents a "positive evaluation" by the participants.

In the final questionnaire, 5.5% of participants favoured the manual modality, 55.5% favored the QR-codes and 38.8% favored the tangibles. Five of those who favored the QR-codes gave the high fabrication and distribution cost of tangibles as explanation. Furthermore, four participants liked that QR-codes are familiar to them. Of those who favored the tangibles, four pointed at the intuitivity and three gave "fun while voting" as explanation. One participant favoured the manual modality due to security perception reasons. As additional feedback, three participants mentioned that they would like to use the tangibles in a polling station setting instead of traditional ballots.

DISCUSSION AND FUTURE DIRECTIONS

Scalability and Representativity. We investigated an election with one race and six candidates, but elections are likely to have multiple races and many candidates. Manual codes and QR-codes are likely to have a better scalability than tangibles in elections with many races and candidates. Future work should investigate these scalability aspects of code voting. The mean age of our sample was 30 years and most participants had an academic background. Therefore, the results are not representative for an electoral roll and future studies should investigate a more representative and larger sample.

Hardware and Distribution. The manual modality can be used on any PC without additional special hardware. Since many countries and institutions distribute invitation-to-vote-letters, these letters could contain the voting credentials and the code sheets. Those could be protected by scratch fields which is the common practise when distribution banking PINs. The QR-code sheets could be distributed the same way, but voting requires special hardware that can scan the QR-codes. Since most of PCs nowadays have an integrated webcam and practically all mobile devices are equipped with cameras, it is highly likely that a big share of the voters is in possession of the required hardware. Tangibles need to be fabricated for the election and require recognition hardware. If the tangibles are 3D-printed of a conducting and an insulating material, they can be recognized by commercially available touchscreens as those in mobile devices. But the cost for fabrication and distribution is likely to be higher.

Recommendations. QR-codes were perceived as more usable than the other modalities and the participants welcomed, that they previously knew QR-codes. Based on the evaluation results and the fabrication costs, we conclude that QR-codes are the best from the investigated modalities. They should be used in the Internet voting scenario, if it can be assured, that all voters possess the required hardware. Special user groups, such as elderly or blind people, might be disenfranchised by manual or QR-codes, but might be enfranchised by tangibles. Voters belonging to such a group should be allowed to register for tangibles, because the benefits are likely to outweigh the costs. The accessibility of voting tangibles in these special user groups should be evaluated in future work.

CONCLUSION

In this paper, we investigated how voters interact with three different code voting modalities. We adapted the well established PGD voting scheme for vote casting via QR-codes and tangibles and conducted a comparative user study. The results of the study show that QR-codes are preferred by the participants and offer the best usability while tangibles are perceived as novel and fun. The usage of code voting offers a better vote privacy, but influences the usability of the voting scheme. Our evaluation shows, that the usability is dependent on the voting code input modality and can be enhanced. This counterbalances the security-usability trade-off that is present in Internet voting schemes and might support the acceptance of code voting.

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REFERENCES

[1] John Brooke. 1996. SUS - A Quick and Dirty Usability Scale. *Usability Evaluation in Industry* 189, 194 (1996), 4–7.

[2] Liwei Chan, Stefanie Müller, Anne Roudaut, and Patrick Baudisch. 2012. CapStones and ZebraWidgets: Sensing Stacks of Building Blocks, Dials and Sliders on Capacitive Touch Screens. In *Proc. SIGCHI Conference on Human Factors in Computing Systems (CHI '12)*. ACM, 2189–2192.

[3] Alex Escala, Sandra Guasch, Javier Herranz, and Paz Morillo. 2016. Universal cast-as-intended verifiability. In *Proc. International Conference on Financial Cryptography and Data Security*. Springer, 233–250.

[4] David Galindo, Sandra Guasch, and Jordi Puiggalí. 2015. Neuchâtel's Cast-as-Intended Verification Mechanism. In *Proc. International Conference on E-Voting and Identity (VoteID)*. Springer-Verlag, 3–18.

[5] Dawid Gaweł, Maciej Kosarzecki, Poorvi L Vora, Hua Wu, and Filip Zagórski. 2016. Apollo–End-to-End Verifiable Internet Voting with Recovery from Vote Manipulation. In *Proc. International Joint Conference on Electronic Voting*. Springer, 125–143.

[6] Sven Heiberg and Jan Willemson. 2014. Verifiable Internet Voting in Estonia. In *Proc. International Conference on Electronic Voting: Verifying the Vote (EVOTE)*. IEEE, 1–8.

[7] Bettina Laugwitz, Theo Held, and Martin Schrepp. 2008. Construction and Evaluation of a User Experience Questionnaire. In *Proc. HCI and Usability for Education and Work*. Springer, 63–76.

[8] Karola Marky, Oksana Kulyk, Karen Renaud, and Melanie Volkamer. 2018. What Did I Really Vote For? On the Usability of Verifiable E-Voting Schemes. In *Proc. CHI Conference on Human Factors in Computing Systems (CHI '18)*. ACM, New York, NY, USA, Article 176, 13 pages.

[9] Jun Rekimoto. 2002. SmartSkin: An Infrastructure for Freehand Manipulation on Interactive Surfaces. In *Proc. SIGCHI Conference on Human Factors in Computing Systems (CHI '02)*. ACM, 113–120.

[10] Peter Y. A. Ryan and Vanessa Teague. 2009. Pretty good democracy. In *International Workshop on Security Protocols*. Springer, 111–130.

[11] Martin Schmitz, Jürgen Steimle, Jochen Huber, Niloofar Dezfuli, and Max Mühlhäuser. 2017. Flexibles: Deformation-Aware 3D-Printed Tangibles for Capacitive Touchscreens. In *Proc. CHI Conference on Human Factors in Computing Systems (CHI '17)*. ACM, 1001–1014.