Investigating Transparency Dimensions for Internet Voting

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Abstract. While Internet voting is argued to have the potential to improve election processes, concerns about security risks remain one of its main adoption barriers. These concerns are furthermore aggravated by the lack of *transparency* of Internet voting systems that are often perceived as a "black box". Moreover, there is a research gap in conceptualizing the idea of transparency and in studying voters' attitudes towards transparency in Internet voting. In this work, we aim to address this gap by (1) Conducting a systematic literature review, from which we identified five dimensions of transparency; (2) Developing a questionnaire (Transparency Dimensions of Internet Voting, TDIV) to assess voters' attitudes regarding the correlation of these dimensions with transparency; and (3) Conducting an online study (N = 500) to investigate voters' attitudes towards transparency in Internet voting. We conclude that providing information about the security of the Internet voting system; testing it by independent experts for security vulnerabilities prior to the election; monitoring the election process and verifying its integrity; and providing a remedy for security breaches while holding the responsible parties accountable, are perceived by voters as important, and enhance transparency in Internet voting systems.

1 Introduction

Internet voting has been an active topic of public discussions for many years. Its proponents highlight the advantages of voting online, such as increased convenience and accessibility for voters who might have difficulty reaching a physical polling station.

However, critics of Internet voting raise concerns about its security risks, including the potential manipulation of election results and violation of vote secrecy. Addressing these risks and ensuring voters' trust in the security of the system is particularly challenging given the complexity of Internet voting systems and corresponding security measures. One crucial aspect in establishing trust is *transparency*. Transparency allows the public to monitor the voting system's

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workings and ensure that the election follows proper procedures. Numerous studies [1,9,21] have confirmed the importance of transparency, as also recognized by the German Constitutional Court concerning the use of voting machines [10]. Despite technical proposals to enhance transparency in Internet voting [22,30], little attention has been given to understanding voters' attitudes towards transparency in Internet voting and the proposed measures.

In this work we aim to bridge this gap and to investigate voters' attitudes toward the transparency of Internet voting, our study aims to address the following research question: *What are the measures that can be used to increase transparency in Internet voting systems as proposed in academic research and applied in practice, and what are the voters' attitudes towards these measures and their relation to transparency?*

Our contributions are therefore as follows:

- We conduct a systematic literature review on measures proposed to improve transparency in Internet voting, supplementing the results of our review with a further search on transparency in other domains of technology, such as AI. We propose a taxonomy of these measures by deriving five dimensions, namely, *information availability*, *understandability*, *monitoring and verifiability*, *remedial measures* and *testing*. These differ depending on the involved stakeholders, time period when these measures are applied (e.g. before or during the election) and their effect.
- Based on the taxonomy we develop and empirically validate (N = 50) a questionnaire which we call "Transparency Dimensions of Internet Voting" (TDIV) which is designed to measure voters' assessment of the five dimensions of transparency in Internet voting systems as well as transparency in general (as overall attitudes and as related to specific systems)
- We conduct an online user study (N = 500) by applying the TDIV questionnaire in order to study voters' attitudes towards the measures across the five transparency dimensions and transparency in general. In particular, we conduct a quantitative analysis studying the relationship between the perceived importance of individual dimensions and the perceived importance of transparency in Internet voting in general.

Our findings show that voters' perceptions of four out of five proposed dimensions (namely, *information availability*, *monitoring and verifiability*, *remedial measures*, and *testing*) indeed correlate with their perceptions of transparency in Internet voting in general. Thus, our results confirm that providing information about the security and data protection measures used in the election, opportunities both for experts and general public to thoroughly test the voting system prior to the election and to verify the integrity of the election procedures during/after the election, as well as having a remedial plan for the election in case of security breaches indeed has a potential to have a transparency-enhancing effect on Internet voting systems. On the other hand, our study shows mixed effects of *understandability* of the voting system; while some participants mention the importance of being able to understand how the system works, we did not find a

significant correlation between the attitudes towards understandability and attitudes towards general transparency, indicating the need for future investigations to better understand the relationship between these two concepts.

The remainder of the paper is as follows: In Sect. 2 we describe the methodology and the results of our literature review, concluding the section with the description of our derived five dimensions of transparency together with hypotheses based on these dimensions that we evaluate in our studies. In Sect. 3 we describe the development and evaluation of the TDIV questionnaire, followed by the description of the methodology for the follow-up study using the questionnaire. Section 4 describes the results of the study. The paper concludes with us discussing our results and their implications for future research in Sect. 5.

2 Literature Review

We describe the systematic literature review conducted to define the concept of transparency and identify its different dimensions as well as the proposed hypothesis.

We used the following search phrases: *("Transparency" OR "TRANSPARENCY" OR "Openness" OR "Understandability") AND ("Internet Voting" OR "INTERNET VOTING" OR "E-VOTING" OR "E-voting" OR "Online Voting" OR "Remote Voting").* We ran a manual search of databases such as Springer, IEEE, Scopus, Web of Science, ProQuest, and Emerald Insight. We also looked into research publications in the proceedings of the E-Vote-ID conference[1], which is one of the leading conferences dedicated specifically to the subject of electronic voting. Two paper authors evaluated the publications for their relevance to the research inquiry. Our inclusion criteria considered publications published between 2015 and 2022 on transparency and technology in general, as well as empirical and theoretical papers. Technical papers, non-empirical papers, papers that did not discuss transparency and trust, and papers that were not written in English were all excluded. We reviewed the abstracts of the remaining papers and eliminated those that were not relevant to the research topic or aims. Finally, the snowballing approach was used in reviewing the papers. The authors used this method by reviewing the reference list of the initial set of papers extracted and selecting additional relevant papers, which were then added to the list. The review included a total of 21 papers in total.

Based on the reviewed papers, the five main dimensions, *Information Availability*, *Understandability*, *Monitoring and verifiability*, *Remedial Measures*, and *Testing* were identified through an iterative discussion process.

In the following subsections we describe the results of our search, starting with an overview of studies on how transparency of technology influences users' attitudes towards this technology, namely, trust. We then elaborate on our conceptualisation of transparency in Internet voting, describe the five identified dimensions of transparency and provide the hypotheses related to these dimensions that inform our follow-up studies.

[1] https://e-vote-id.org, last accessed on 09.02.2023.

2.1 Effects of Transparency on Trust

Transparency in Information Technology. A number of studies have investigated transparency in the context of information technology and how it influences user attitudes. Some of these studies are in the domain of machine learning (ML) and decision support systems [4,17,31], automation systems [19,37], social media algorithms [27] and automatic online comment moderation systems [5]. However, the findings of these studies are inconclusive; for example, Schmidt et al. [31] investigated how users' understanding of the ML-based decision support system affects their willingness to trust the system's predictions. The findings show that transparency, or users having insight to the ML-based decision support tool, negatively impact users' trust in the ML decision support system's predictions [31]. This implies that gaining more insight into the internal logic of the system, it may have a negative impact on users' trust. This finding is also supported by Kizilcec's [17] work, which claims that trust can be influenced by the level of transparency; that is, low and high levels of transparency can decrease users' trust, while medium levels of transparency can increase trust [17]. In contrast, Lyons et al. [19], Yang et al. [37], and Brunk et al. [5] found that transparency increased users' trust in technology.

Transparency in Election Technologies. At the time of writing only few studies have investigated transparency in the context of election technologies, such as electronic voting. For instance, Driza Maurer [7] reviewed how to develop systems that increase transparency to improve voter confidence by identifying design requirements such as verifiability, public intrusion testing, and source code publication. Buckland, Teague and Wen [6] discovered that there is little information available about the Australian electronic voting system, and that the source code and technical documentation are not publicly available. The authors conclude that the lack of transparency negatively influenced voters' attitudes toward the electronically held elections. Note that one of their key recommendations is that source code, technical documentation, user and training manuals, and audit reports should be made public. Volkamer, Spycher and Dubuis [36] concluded that transparency in election technologies is key to voters overall trust and could positively influence voters behaviour towards electronic voting. While these studies have looked at transparency in electronic voting system, they did not fully examine the various dimensions of transparency, that is, there is lack of research for conceptualising transparency. Saldanha et al. [30] attempted to identify the characteristics of transparency in the Brazilian electronic voting system but failed to investigate the significance of these characteristics and how they influence transparency. We complement their work by conceptualising transparency and examining the importance of its various dimensions for voters in the context of Internet voting.

2.2 Conceptualisation of Transparency

Transparency has been defined as the process of ensuring that a system is open and externally accessible to the public [33], as well as the availability of

information about the election system and the actors [11]. Jain and Jain [16] also argued that transparency is about information disclosure and openness. Studies have also shown that a transparent election system is the one that supports verifiability of votes, observation and monitoring [22], accountability, as well as public oversight, and comprehension of the election process [15]. Furthermore, Saldanha et al. [30] also identified several characteristics of transparency in election technology, including consciousness, accountability, explanation, and finally testing and auditing. As a result, in the context of our work, transparency is defined as having characteristics such as information availability, understandability, monitoring and verifiability, remedial measures, and testing [11,15,22,30,33], which are further elaborated in the following sections.

Information Availability. The ability to make information about the election system, specifically the Internet voting system, available to relevant stakeholders is referred to as *information availability* [7]. This information could include source code, technical documentation, vendor information and user manuals [7,11]. It is important to emphasise that information availability about Internet voting has been argued to influence transparency [7,15]. Hall [15] argued that even if voters do not understand the source code, the fact that it is available may increase transparency. That is, once the source code is published, experts can review it for any hidden bugs. Note, that level of accessibility of the provided information can vary: as such, some of the information can be made available either publicly or upon request only; similarly, some of the information such as technical documentation might require a relatively high level of expertise to understand it.

Understandability. Is the ability to explain in a way that a lay person can understand how the system works, and in particular, given the concerns about security risks of Internet voting, the extent to which security of the system is guaranteed. Note, while this category is similar to information availability in terms of providing information about the workings of the voting system, the important distinction is that measures aimed at understandability imply that everyone, as opposed to just the experts, can understand the provided information. For example, Saldanha et al. [30] found that explaining the algorithm and security protocols, as well as how the system works, can positively influence voters' attitudes toward transparency. Similarly, "understandability" was identified as a characteristic of transparency in the work of Spycher et al. [34].

Monitoring and Verifiability. Refers to a variety of measures implemented *during* or *after* the election in order to ensure that the election processes run according to a proper procedure. In particular, *end-to-end verifiability* has been widely advocated for by election security experts as a means to detect election manipulations, proposing techniques that enable voters to verify that their own vote has been correctly cast, stored and tallied (individual verifiability) as well as techniques that enable the general public to verify that the stored votes have been tallied correctly [22,26]. Other methods aimed at ensuring the correctness of election processes can include non-technical measures such as ensuring that the

important steps of voting and tallying are observed by independent parties. The availability of a vote verification process, according to Solvak's [32], increases voters' confidence that their vote was cast correctly. To improve transparency, many electronic voting system implementations have included verification processes. Puiggali et al. [26], for example, identified countries such as Norway, Switzerland, Estonia, and Australia that have implemented some form of verifiability in their electronic voting system to increase transparency.

Remedial Measures. The various methods for dealing with situations in which something goes wrong, including security breaches as well as other issues that might jeopardise the integrity of the election. This includes both error-correction measures and accountability measures that allow for the identification of individuals or entities responsible for these errors [30]. Voters, for example, may perceive an Internet voting system as transparent if the system can detects errors or breaches, implements corrective measures, and identifies the entities responsible for these breaches [12].

Testing. Refers to the various measures taken *prior* to the election to ensure that the Internet voting system is sufficiently secure. This includes code review measures, public intrusion tests, formal verification, and other auditing-related measures, in particular ones allowing the general public to to participate in the testing and resolution of any discovered vulnerabilities, which can improve transparency [7,25,30].

2.3 Hypotheses

Given the identified dimensions of transparency in Internet voting, we conduct an empirical evaluation in order to understand whether these dimensions are indeed perceived as related to transparency by voters. In doing this, we follow an indirect approach of studying whether the perceived importance of any of the dimensions is correlated with perceived importance of transparency. Such an approach allows us to investigate voters' attitudes independent of a particular voting system, which is of benefits when studying the attitudes of populations that did not yet have experience with voting online. We therefore define the following hypotheses:

H1: There is a positive correlation between perceived importance of information availability and voters' attitude towards transparency.
H2: There is a positive correlation between perceived importance of understandability of Internet voting system and voters' attitude towards transparency.
H3: There is a positive correlation between perceived importance of verifiability of Internet voting system and voters' attitude towards transparency.
H4: There is a positive correlation between perceived importance of remedial measures and voters' attitude towards transparency of Internet voting system.
H5: There is a positive correlation between perceived importance of testing and voters' attitude towards transparency of Internet voting system.

3 Methodology

This section describes the methodology for developing and evaluating the questionnaire, as well as for the study conducted using the questionnaire to investigate the defined hypotheses.

Our goal when developing the questionnaire was two-fold. First, we wanted to propose an instrument that can be used in future studies to evaluate voters' perception of each transparency dimension with respect to any Internet voting system (e.g. whether the voters believe that there is sufficient information provided by the system, that is, the extent to which information availability is ensured). Second, we wanted to understand the relations between individual dimensions of transparency and their related measures, as well as the perceived transparency in general.

As currently very few countries have implemented Internet voting for legally binding elections, we assumed that our questionnaire will target mostly people who do not have a particular system in mind when asked about Internet voting. Nevertheless, our questionnaire can be applied also to people who have used Internet voting, in order to measure and improve the transparency of the corresponding system.

3.1 Questionnaire Development and Testing

Development of TDIV Items. The TDIV instrument consist of the following dimensions (also known as variables or constructs): **Information availability**, **Understandability**, **Monitoring and verifiability**, **Remedial measures**, **Testing** and **Transparency**. Based on the literature review and our internal discussion we added at least four (4) closed-ended questions or items to each variable of the TDIV instrument[2]. Each item consisted of a statement about importance of a transparency-enhancing measure related to a corresponding transparency dimension (e.g. "The documentation on how the internet voting system works should be available to the public" for information availability) or transparency in general (e.g. "Transparency is an integral aspect of internet voting system") with the responses measured using a 7-point likert scale (1- Strongly disagree to 7- Strongly agree).

Validation of the TDIV. To ensure the validity of our TDIV instrument, we conducted a face-to-face validation check [2]. Thereby, we asked three experts (cryptography, election technology and security) to examine the various dimensions or variables and items of transparency. The experts were required to determine any ambiguities or inaccuracies, and check if the items address the research questions. The opinions and ideas of the experts were used to update the dimensions and question items. After the first validation, in order to evaluate that the various transparency dimensions and their items are easy to understand we

[2] The resulting variables are available at https://github.com/cometitu/constructs/blob/main/Codes_constructs.pdf.

conducted a pilot study with a small number of respondents (sample size of 50, that is 10 percent of the sample size for the main study (500), [2]). The pilot study enabled us to adapt the transparency dimensions and their question items when we detected that the respondents were having difficulties understanding them [2]. Based on the results of the pilot study, we slightly adjusted several of the items and removed some of them. We detected these difficulties through the open-ended questionnaire, where we explicitly asked if the participants encountered any issues in the pilot study[3].

3.2 Study Procedure

Our study applying TDIV has been conducted as an online survey using the SoSci Survey platform[4]. We recruited the participants for our survey from the Prolific[5] platform. The participants were recruited from US, UK, Estonia, Denmark, Sweden and Norway.

To reduce the bias that comes with online surveys like prolific, we conducted a pilot test with a small group of respondents before administering to a larger population. It helped us identify any potential issues with the survey. We furthermore used the option to recruit gender-balanced sample, which according to previous research is reasonably representative of general population with regards to security and privacy related research [28]. Each participant received 1.5 UK pound sterling in compensation for an estimated 10 min of participation, which corresponds to the recommendation of the Prolific platform. Following the recommendation by Aithal and Aithal [2], we aimed to recruit a total of 500 participants. In order to control for quality of the responses, we included attention checks in the survey, namely, two Instruction Manipulation Checks (IMC) [24]. In terms of voting experience, most of the participants (59%) did not have any experience with Internet voting, only 16% had experience ranging from good to excellent. At the beginning of the survey the participants were provided with information about the study and asked to provide their consent for participation. Then they were asked about their previous experience with Internet voting, presented with a hypothetical scenario where they were asked to imagine that their country wants to implement Internet voting for the next elections and asked whether they would be willing vote online in such a scenario. They were then presented with the items from the TDIV questionnaire. For each one of the dimensions, the participants were asked an additional open-ended question for their input on further measures they would like to see in an Internet voting system (e.g. "In your opinion what other information should be available about the internet voting system"). At the end of the TDIV questionnaire the participants were furthermore asked an open-ended question about further measures

[3] Items retained for the survey are available at https://github.com/cometitu/constructs/blob/main/Codes_constructs.pdf.
[4] https://www.soscisurvey.de, last accessed 03.02.2023.
[5] https://www.prolific.co/, last accessed 03.02.2023.

that they believe would increase transparency in an Internet voting system. The questionnaire concluded with questions about participants' trust in authorities[6].

Data Analysis. We examined the data after collecting it from the participants for missing values, questionable responses patterns, and data distribution, as common when collecting quantitative data from participants [13]. Furthermore, we tested for outliers and straight line response patterns, and these types of responses were rejected and removed if they also failed the attention checks questions.

For the analysis, the data was analysed using the IBM SPSS statistical program and Partial Least Square Structured Equation Modeling (PLS-SEM) with the SmartPLS software package [29]. We chose this second-generation statistical method (PLS-SEM) over others such as factor or regression analysis because PLS-SEM is suitable for multivariate analysis, it has the capacity to manage and test for complex relationships between independent and dependent variables [13,14]. Note that, even though PLS-SEM is a non-parametric statistical method, it is critical to ensure that the data is not out of normal range, as this can cause mistakes in the results [13]. As a result, we investigated the various measures of distribution, mean and standard deviation (which estimates the amount of data scattered around the mean).

Ethics. Our institution does not require ethical approval for conducting a user study; however, we followed the APA ethical guidelines [3] for conducting both a pilot study and a survey. Before initiating the process, we informed the participants about our study's goals and explained that they could withdraw from the study at any time. According to the privacy and confidentiality section of the APA guideline [3], the participants were informed and assured that their responses would remain confidential and only be used for research purposes. These responses would be used by the researchers involved in the study in an anonymous form during publication. In addition, we also notified our participants before starting the study that attention checks are present and failing them will lead to no compensation from the Prolific platform. We furthermore provided our contact details to participants in case of further questions or concerns.

4 Results

This section presents the findings of the study. We followed a two-step analysis approach, as in PLS-SEM, by evaluating the reflective measurement model followed by the structural model [13,14]. In the evaluation of the reflective measurement model, we assess the model's quality by measuring the relationship between the indicators and the dimensions as well as the relationship between dimensions. Furthermore, we assess the indicator's reliability, internal consistency reliability, convergent validity, and discriminant validity. After assessing

[6] For the sake of brevity, we provide our analysis of these responses in the extended version of our paper.

the quality of the measurement model, we evaluate the structural model by examining the collinearity issues in the model, the path coefficient of the structural model, and the model explanatory power. Note that a total of 514 participants have been recruited for the study, of whom 14 were excluded based on low-quality responses and failed attention checks. (see Table 1 and Appendix A in appendix). Out of the remaining 500, 245 identified as women, 252 as men and 3 as non-binary. More than half of the participants (281) were between ages 18 and 40. The full participant's demographics is provided in Table 1 in the appendix.

4.1 Analysis of the Reflective Measurement Model

To test the reflective measurement model, we first examined its reliability by looking at the indicators' outer loading. The rule of thumb is that the outer loading should be 0.708 or higher [13], and almost all indicators' outer loading exceeded the threshold. However, there were a few indicators that were lower than the acceptable 0.708 but greater than 0.4, for example *InfAv_07 = 0.665*, *RemMs_02 = 0.614*, and *Test_04 = 0.657*. These indicators were kept because their removal had no effect on the reliability or validity of our model [13]. Nevertheless, we removed *InfAv_03 = 0.619* and *RemMs_06 = 0.519*, because these indicators were affecting our "Average Variance Expected" (AVE). Furthermore, we examined our model's internal consistency reliability, by using Cronbach's alpha and composite reliability. However, due to the limitations of Cronbach's alpha [13], we used composite reliability (CR) to assess the internal consistency reliability. Our results, refer to Table 2 in Appendix A, revealed that the CR values were within the acceptable range of 0.60 and 0.90 [13], confirming the model's internal consistency reliability. In addition, we assessed the convergent validity of the identified dimensions. Our results, refer to Table 2 in Appendix A, revealed that the AVE of all the latent variables or the dimensions were above 0.50. This demonstrates that on average all latent variables may account for more than half (50 percent) of the variance of their indicators [13]. Further, we evaluated the discriminant validity. Thereby, we adopted Heterotrait-Monotrait ratio (HTMT), which has been suggested to be a more trustworthy measure to determine discriminant validity [13,14]. Our findings showed that the values were below the acceptable threshold level, that is 0.85, indicating that the identified dimensions are conceptually distinct.

4.2 Analysis of the Structural Model

For the structural analysis we followed the method suggested by Hair et al. [13,14]. First, we examined both the outer and inner models for collinearity issues. Our findings showed that collinearity was not an issue for our model. All the values were below the threshold of 5. Hence, there was no collinearity among the dimensions. Further, we examined the significance of the relationships between the structural model. The results, refer to Table 3 in Appendix A, showed that information availability ($\beta = 0.175$, p = 0.003), monitoring and verifiability ($\beta = 0.217$, p = 0.000), remedial measures ($\beta = 0.225$, p = 0.001),

and testing ($\beta = 0.217$, p = 0.000) have a positive correlation with transparency. Thus, **supporting the hypotheses *H1*, *H3*, *H4* and *H5***. However, there was no correlation between understandability ($\beta = -0.018$, p = 0.746) and transparency. Hence, the hypothesis ***H2* was not supported**. From the findings, shown in Table 4 in Appendix A), it can be inferred that remedial measures (0.225) have the strongest correlation with transparency, followed by testing, and monitoring and verifiability (0.217), while information availability (0.175) has only a minor correlation. Finally, we investigated our model's explanatory and predictive power. We looked at the coefficient of determination (R^2) of our endogenous dimension (transparency) to test its explanatory power. We found out that our model had 40% explanatory power for transparency, with a R^2 of 0.407. This indicates that our model has moderate explanatory power [14]. To evaluate our model's predictive power, in particular to assess whether our model can be generalisable and make future predictions using different data sets, we used the "PLSpredict" procedure proposed in [13,14]. Thereby, we assessed the dependent variable "transparency" and its root mean square error (RMSE), as well as Q^2 predict. This means that we compared the values generated by PLS-SEM RSME against the values produced by linear regression model (LM) benchmark. The results from our analysis showed that all values for the "transparency" indicators in the PLS-SEM_RMSE (Trans_01, Trans_02, Trans_03, Trans_04) were lower than the values for LM_RSME. Consequently, our model has a high predictive power. The Q^2 predict values for the indicators (Trans_01, Trans_02, Trans_03, Trans_04) were all greater than zero, confirming that the our path model performed better than the LM benchmark.

5 Discussion and Conclusion

It has been argued that transparency in Internet voting increases voter's confidence and trust [1,9]. Therefore, our goal in this study was to investigate voters' attitudes towards transparency in Internet voting. Our findings revealed several groups of measures (dimensions) that are important to voters in terms of Internet voting transparency. The findings from our study showed that participants' attitudes towards information availability, monitoring and verifiability, remedial measures, and testing are strongly correlated with their perceived importance of transparency, suggesting that proper implementation of these measures is of significant importance to ensure voters perceiving an Internet voting system as transparent.

The findings demonstrated the significance of making documentation about the Internet voting system publicly available. Such documentation should demonstrate how the Internet voting system functions, as well as the underlying security mechanism(s). Voters also want public information about the vendor(s) who supplied or developed the Internet voting system, allowing them to determine whether the acquisition or implementation of the Internet voting system was not influenced by the government or political parties. As providing such information is inline with common recommendations by election experts [6], our findings confirm its importance.

Our findings also revealed that individual and universal verifiability as well as other measures implemented to monitor the integrity of election processes are linked to voters' positive attitudes toward the transparency of the Internet voting system. The argument that implementing verifiability measures is necessary for voters' trust and perceived transparency has been put forward by previous research [1,20], as well as supported by other previous studies in the context of Estonian elections [32]. It is worth noting, however, that the attitudes towards verifiability can be paradoxical. Some studies show that voters do not understand the purpose of verifiability and do not see the need to conduct the verification themselves [23]. Furthermore, empirical data from real-world elections show low verification rates among the voters (e.g. around 5% in Estonian elections [8]). It can therefore be argued that while the presence of verifiability options can and does serve as an assurance to the voters, more work needs to be done to ensure that it is understood and utilised to its full extent.

Furthermore, in terms of remedial measures, the findings suggest that stakeholders should not only make an effort to implement measures to detect and prevent any security breaches that may occur during the voting process but also make sure that the existence of such measures and the extent to which independent experts have audited them is properly communicated to the voters. Another aspect of further critical importance is ensuring that the voters have an opportunity to be involved in safeguarding the election process by making sure that explanations regarding the security of the Internet voting system are available to the voters who are interested to know more about them, and by providing easily accessible avenues for voters to report any security issues. Even though studies [30] have found that measures such as accountability do not influence voters' attitudes toward transparency, our findings showed otherwise. Furthermore, our findings showed that voters are much more concerned with the security assurances and safeguards put in place, and they associate this with the transparency of the Internet voting system.

The study also provided sufficient evidence that testing the Internet voting system by experts and the general public prior to its' use has a significant impact on voters' attitudes towards the transparency of the system. Such an approach, in particular, has been used for the Swiss voting system, which provided opportunities for public testing, including election security experts. While the testing revealed a number of serious vulnerabilities, preventing its use in the election, its contribution to the transparency of Internet voting elections was commented positively by experts [7]. Our study showed, that this is likely to be positively perceived by the voters as well.

However, there was insufficient evidence from our study to support that understandability has a correlation to voters' attitudes toward Internet voting transparency. One possible explanation is that while understanding the Internet voting system may be important to voters (e.g. improving their self-efficacy in using the system to vote), it is not necessarily perceived as contributing to transparency. Indeed, previous research shows that voters' understanding of an Internet voting system does not necessarily contribute to voters' trust in the sys-

tem and might even have a negative impact [38]. Thus, a relationship between understandability, transparency and trust might have a paradoxical nature, in that voters believe that they need to understand how the system works in order to see it as transparent and/or trustworthy, but their actual reactions to being provided with explanations demonstrate a different effect. Therefore, further investigations regarding this *understandability paradox*, which might have similar explanations as the so-called *privacy paradox* [18], are needed.

Finally, while the proposed measures can potentially improve transparency of the voting system and reduce security risks, they have their own limitations that need to be acknowledged, such as verifiability techniques often being difficult for the voters to apply [35] or difficulties in addressing threats such as voter coercion. The decision on whether to provide the option to vote online should therefore be made on case-to-case basis by experts from both technical and social disciplines, and in case such an option is provided, additional channels (e.g. traditional voting in polling places) should be offered to voters who either prefer not to vote online or experience issues with the voting process (as done e.g. in Estonian elections [8]).

Limitations. Despite the fact that the findings highlighted several important aspects of transparency, the survey has some limitations that must be considered. First, as only a few countries implement Internet voting on a large scale, most of our participants did not have personal experience with Internet voting systems. While their experiences still provide valuable insights for introducing Internet voting in countries without such prior experience, the extent to which our findings would differ in countries with extensive history of Internet voting such as Estonia remains to be studied.

Future Work. Our study focused on correlations between voters' perceived importance of various types of measures that are commonly treated as transparency-related by researchers and practitioners when applied to Internet voting, as well as the perceived importance of transparency in general. To further validate our findings more research (e.g. in form of a controlled experiment) is needed to understand whether the presence of these measures in a voting system has a significant effect on perceived transparency of the system, as well as on trust and willingness to use the system for real-world elections. A particular interesting research direction would be to further investigate the effects of understandability. As our study showed mixed results, the extent to which understandability influences perceived transparency and trust, as well as the appropriate ways to provide understandability (e.g. determining the contents as well as the media for provding voters with explanations about the system).

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A Appendix

Table 1. Participants demographic attribute

Attributes	Dist	Freq	Per
Gender	Female	245	49
	Male	252	50.4
	Non-binary	3	0.6
Age	18 to 30	130	26
	31 to 40	151	30.2
	41 to 50	82	316.4
	51 to 60	68	13.6
	61 to 70	59	11.8
	71 and above	10	2
Education	High School	179	35.8
	Bachelor's degree	84	41.4
	Master's degree	207	16.8
	PhD	13	2.6
	Others	17	3.4

Table 2. Internal Consistency Reliability

	CR	AVE
Info. availability	0.855	0.597
Remedial	0.842	0.574
Testing	0.778	0.540
Transparency	0.922	0.748
Understandability	0.889	0.616
Mon. and Veri	0.848	0.584

Table 3. Path Coefficients

	Path Coefficients	P – values	Confidence intervals		Significance
			Lower	Upper	($p<0.05$)
H1:Info availability->transparency	0.175	0.003	0.066	0.294	Yes
H2:Understandability->transparency	–0.018	0.746	–0.121	0.095	No
H3:Mon. and Veri->transparency	0.217	0.000	0.111	0.325	Yes
H4:Remedial->transparency	0.225	0.001	0.088	0.360	Yes
H5:Testing->transparency	0.217	0.000	0.116	0.319	Yes

Table 4. Significant Path Coefficients

	Path Coefficients	P – values
H1:Info availability->transparency	0.175	0.003
H2:Understandability->transparency	–0.018	0.746
H3:Mon. and Veri.->transparency	0.217	0.000
H4:Remedial->transparency	0.225	0.001
H5:Testing->transparency	0.217	0.000

Note: Significant at P = .05

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