Modelling Trust: An Empirical Assessment

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Abstract. Trust has shown to be a key factor influencing user uptake and acceptance of technologies. Despite the increase in interest in trust research and its stated importance in HCI, prior research has mainly focused on understanding its role in human to human interactions mediated through technology. The ongoing and rapid technological developments have made it necessary to move beyond studying trust relationships between people mediated by information technology (IT) and focus on studying the relationship of the user with the IT artifact itself. We recognize that HCI discipline lacks a focused body of knowledge on trust and there is a lack of theoretically grounded and robust psychometric instruments for quantifying trust. With this in mind, this article is aimed at empirically evaluating a socio-technical model of trust so as to assess its feasibility in user technology interactions. Using prior established measures and theories, we identify seven trust attributes and test the proposed model using partial least square structural equation modelling (PLS-SEM). Our study contributes to the literature by advancing the discussion of trust in human-artefact relationship.

Keywords: Trust in technology · Theory development · PLS-SEM

1 Introduction

The field of Human computer interaction (HCI) has witnessed tremendous growth over the past decade. The place that information technology has in people's lives has drastically changed as technology has now become seamlessly integrated and diffused into every aspect of a person's life. People are getting more engaged, involved and reliant on technology for their day to day tasks. Considering the kind of technology being developed and the rate at which it is being developed, it is safe to say that computing is at one its most exciting moments, playing an essential role in supporting human activities, facilitated by growing availability of services, devices and interaction modalities, all associated with tangible consequences [67]. This is also supported by Häkkinen [24] who recognize the seamless integration of technology into modern life and call for theoretically sound and empirically grounded research to explore such a wide swath of technological applications (p. 1).

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In light of such exciting developments, uncertainties and increasing dependency on technologies, there has been a greater call among scholars to understand and research trust within HCI [5,37,64]. The main reason for this can be attributed to the fact that trust has shown to be a key factor in technology adoption and user satisfaction with technology [32,63] and its absence could lead to a user proceeding more cautiously when using the technology and taking unnecessary time to think through their actions, which will ultimately lead to dissatisfaction, failure to continue using the system and the user not being able to fully realize the potential which the technology has to offer [9]. However, despite the benefits of studying trust in technology, the HCI community is lacking a coherent & focused body of knowledge on trust that can be referred to for developing systems which would foster trust [34]. There is also a lack of theoretically grounded and robust psychometric instruments for quantifying trust [64]. Finally, the HCI discipline needs deepening of understanding the role of trust in a user-artefact relationship [4,37,63,69].

With this in mind, the main aim of the present article is twofold: (1) First, we address the need for a dedicated model to quantify trust in the HCI domain. To advance this discussion, we wish to refine and empirically assess the suitability of socio-technical model (STM) of human computer trust proposed by Sousa et al. [67] in user technology interactions and (2) secondly, we advance the discussion on understanding the role of trust with technological artefacts and suggest directions for future research on the topic.

1.1 Research Questions

As explained earlier, the present study is aimed at empirically assessing and refining the human-computer trust model [67]. The research questions associated with achieving this goal are as follows:

RQ1: How well do the proposed attributes of STM predict trust levels of a user with a system? In other words, is there a statistically significant relationship between these attributes and trust?

RQ2: Which attributes of the STM hold true in case of user technology interactions?

2 Background

One of the earliest scholarly works that addressed trust between humans and technology is that of Muir [48] who developed a trust model for studying human-machine relationships. This model by Muir was based on a prior model developed by Rempel et al. [56], which focused on understanding the role of trust in interpersonal relationships. Interestingly, in both these works, the notion of predictability was of prime importance. In the case of Muir [48], the amount of trust that a human has on a machine would be estimated based on the predictability of the machine's behavior. On similar lines, the study by Rempel et al. [56] found out that couples who can predict how their partners would behave with them in certain situations decides how much they will trust them in a given situation. This work by Muir [48] was further extended by Lee and Moray [38,39] who in their studies to understand trust levels of machine operators with regards to automating their tasks pointed out that when machine operators are able to predict how the machine would behave in different circumstances, trust levels would be higher. However, they also observed that most of the times, the operators were reluctant to switch to automation because of the complexity of the machines. Due to this inherent complexity, the willingness of the operators to trust how the machine would act if given control was low.

Although research on trust was slowly progressing at this stage, Mayer et al. [43] pointed out certain deficiencies with these researches. Specifically, they pointed out three issues which were (1) Lack of understanding in the literature regarding how trustful relationships are developed between trustor(s) and trustee(s), (2) Confusion between trust and its antecedents and outcomes and (3) Problems with regards to defining trust. To address these concerns, Mayer et al. [43] proposed a model of trust and its antecedents and outcomes which was formed as a result of aggregation of research from multiple disciplines. Their model incorporated ability, benevolence and integrity as main antecedents of trust. This model was further extended by McKnight et al. [46] who proposed a theory of initial trust formation by bringing together dispositional, situational and interpersonal constructs to explain trust formation from four divergent research streams.

Researching role and effect of trust in technology gained prominence soon afterwards with plethora of scholarly research emerging on the topic in several disciplines such as group collaboration [7], e-commerce [45], e-Government [3] and social networks [36]. The increased interest in trust research is also in line with the seminal work of Luhman [41] who envisioned that "*one should expect trust to be increasingly in demand as a means of enduring the complexity of a future which technology will generate*" (p. 16).

2.1 Relevance of Trust in HCI

Before discussing the relevance of trust in HCI, it is important to understand the different school of thoughts regarding trust. Is trust really relevant in HCI? Should researchers even worry about trust? The issues of whether to study the role of trust with IT artifacts is an ongoing and a vivid discussion in our field [63]. The first view is that of Friedman et al. [16] who opine "*people trust people, not technology*" (p. 36). They argue that unlike humans, technology does not possess moral agency and the ability to do right or wrong and hence it should be viewed as being a participant in a trust-distrust relationship between a user and the person who programmed the technology. This view is also held by Olson and Olson [55] who argue that when people interact through technology, it is not the technology that needs to be trustworthy. Instead, the trust-distrust relationship is between two humans independent of whatever technology they would use. Similarly, Shneiderman [62] also claims that "*if users rely on a computer and* *it fails, they may get frustrated or vent their anger by smashing a keyboard, but there is no relationship of trust with a computer*" (p. 58). Essentially, these views can be distilled to the following two points, which are:

– People cannot enter into a relationship with technology, and
– The question of people trusting the technology does not arise as people cannot develop a trusting relationship with technology because it lacks volition and moral agency.

However, both these views are extremely narrow and can easily be refuted. Firstly, research has demonstrated that computers can act as social actors and people can enter into relationships with and respond to them in a way comparable to responding to other people [4,53]. Studies have shown that people assign personalities [51], gender [52] and readily form team relationships with computers and consider them as teammates [50]. In their work on understanding anthropomorphism of technology, Waytz et al. [72] defended the notion of people having a human like relationship with a computer by putting forth "*Anthropomorphizing a nonhuman does not simply involve attributing superficial human characteristics (e.g., a humanlike face or body) to it, but rather attributing essential human characteristics to the agent (namely a humanlike mind, capable of thinking and feeling)*" (p. 113). Essentially, it is possible to associate human like characteristics to technology such as benevolence, competence, integrity etc. and perceive it as a social actor [4].

Similarly, users can enter into trusting relationships with a technological artifact. A study by McKnight et al. [44] showed that people can and do develop a trusting relationship with an IT artifact such as Microsoft access or excel. The authors recognize the fact that trust in technology helps in shaping people's belief and behavior towards the technology. A similar assertion is also made by Lankton et al. [37], who empirically demonstrated that not only can people develop trust with technological artifacts but they also associate technology as having human like characteristics. Human computer trust becomes even more important when considering the increasingly non-deterministic and distributed nature of computing [33]. The latter has led to an increase in interest in trust research within the IS and the HCI community as scholars get engaged in identifying technological attributes that would make it more trustworthy [36,63,69]. Therefore, not only do people perceive technology to have human characteristics, but they also form trusting relationships with technological artifacts.

Concerning the role of trust within HCI, it has shown to be a key factor in reducing risk and uncertainty associated with a technological interaction, creating positive and meaningful experiences with technology and is crucial in helping a user adopt and maintain a gradual and steady relationship with the system [37,44,63].

2.2 Research Gap

Despite the relevance and the crucial role that trust plays in HCI, there exists a strong emphasis in the literature on understanding its role in human to human interactions mediated through technology, and neglecting technology's social presence and social affordances and also ignoring its effectiveness as a communication medium [37]. This view is supported by Söllner et al. [63] who put forth that as technology matures, it is necessary to move beyond studying trust relationships between people mediated by IT and focus on studying the relationship of the user with the IT artifact itself. As has already been pointed out that people form trusting relationships with computers and assign them human characteristics. In light of this, a comprehensive socio-technical approach taking into account user's interaction with technology is needed as this would help us determine what exactly it is about technology which makes it trustworthy [44]. Therefore, HCI discipline needs deepening of understanding the role of trust in a user-artefact relationship where the artefact is considered as a trustee and not merely a mediator of information [4,37,63,69].

One of the factors underpinning the research problem is the challenge in defining and measuring trust due to its multi-dimensional nature [40]. This view is supported by Knowles et al. [34] who put forth that HCI discipline still lacks a focused body of knowledge on trust which can be referred to for developing systems which would foster trust. There is also a lack of theoretically grounded and robust psychometric instruments for quantifying trust [64]. One of the earliest works towards a psychometric instrument to measure trust in HCI is that of Madsen and Gregor [42] who developed a human computer trust scale but there is no full validation which has been reported on this and the empirical validity of the scale is questionable because of its low sample size. Another recent attempt at quantifying trust in HCI is that of Rieser et al. [59], who built on prior work by Mayer et al. [43] and McKnight et al. [45] and proposed a semantic differential scale to measure trust but such scales are difficult to analyze, require more cognitive effort on the part of the respondent and therefore can be harder to respond to when compared to likert scales [66]. There have been other empirical attempts to come up with statistical models and scales to measure trust [18,36,45]. However, these are proposed within a particular context such as e-commerce or social networking and the results are difficult to generalize. These limitations are also recognized by the authors themselves but there has been little attempt made within the literature to move beyond them. In their review on empirical nature of trust in technology research, Söllner and Leimeister [64] criticized empirical and methodological rigor of trust models which exist in the literature and call for future research in terms of developing trust models and scales. Finally, Riegelsberger and Sasse [57] have also proposed ten principles that can be used to develop systems that foster trust but their work is conceptual and is not empirically validated.

The present state of trust research can be regarded as being incoherent and there is a need to unify the existing body of literature so as to develop a systematic and a sound theoretical framework which would help identify the core elements of trust [11]. As Li [40] rightly puts forth "*we do not have a generally accepted framework or model to integrate the core elements that constitute the contextual components across diverse disciplines in social studies*" (p. 83). From a HCI stand point, this holds true as there have been calls to come up with a dedicated and robust model and scales for trust and advance theoretical and empirical research on trust [58,63].

With new ICT's, there is a need to develop new frameworks and models to explain trust formation and maintenance which would complement the existing ones [29]. Therefore, a careful approach would not be to refute the existence of these prior models but to extend the existing body of knowledge on trust and come up with new research ideas on conceptualizing trust to have a sound theoretical base to understand trust in technology. This becomes even more important when we consider the ongoing and rapid technological developments in HCI, in light of which there is a need to re-examine, strengthen and extend current theories to ascertain how these can be epistemologically revised [13].

3 Hypothesis Development

Before discussing hypothesis formulation, it is important to point out why we are interested in refining the human computer trust model. This model was proposed by Sousa et al. [67] to study the role of trust in technology mediated interactions and was developed as a result of participatory design sessions with users, extensive literature review on trust and was based on the combination of unification of Davis [10] and Venkatesh et al. [70] technology acceptance models. However, the trust attributes proposed in this model had not been empirically assessed in terms of how much they explain trust. The main aim of our research was to assess which aspects of this model hold true in human technology interactions and contribute towards developing an instrument for trust measurement in HCI. In this section, we further refine, explain and define the different components of the model (as shown in Fig. 1), along with associated hypothesis that can be empirically tested.

3.1 Motivation

We define Motivation as the degree to which an individual believes (even under conditions of vulnerability and dependence) in themselves to carry out certain technologically oriented tasks. We explain this through the concept of self-efficacy, a notion grounded in the social cognitive theory (SCT), which acts as a theoretical framework for analyzing human motivation, thought and action and at its very core the theory holds the view that humans acquire and maintain certain behavioral patterns which are determined by a dynamic interaction between people and environments and central to this interaction is the concept of self-efficacy [2]. According to Bandura [2], "*people's self-efficacy beliefs determine their level of motivation, as reflected in how much effort they will exert in an endeavor and how long they will persevere in the face of obstacles*" (p. 1176).

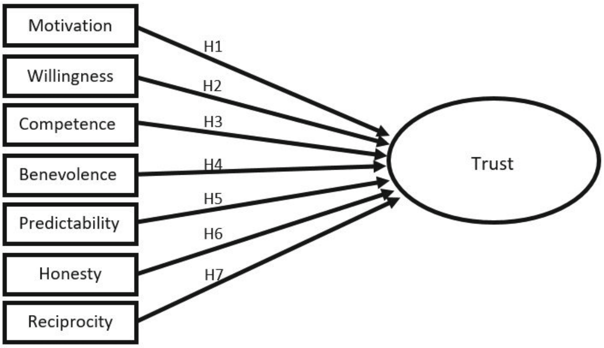

Fig. 1. Model under investigation

Essentially, the stronger the belief an individual has in their abilities, the more motivated they would be to carry out a certain task and their efforts would be more persistent. Studies have shown that self-efficacy has a direct affect (positive or negative) and acts as a precursor to understanding levels of motivation of an individual when performing a task. For instance, people with high level of self-efficacy are more likely to complete a task and persist longer in their efforts to complete the task. Similarly, people with low self-efficacy have less motivation to carry out a task and tend to avoid performing these tasks [2,61]. Since self-efficacy is domain specific [2], we are specifically interested in Computer self-efficacy (CSE). CSE is an individual's inherent belief in themselves in whether or not they feel that they can execute a technologically oriented task [8]. Prior research [30] done on CSE has shown that a user would engage in an activity or attempt to use a system if they feel it is worthwhile and if they have the belief and the motivation that they would be successful. In essence, these scholarly works present self-efficacy as an important determinant of motivation of a user to use a system.

Correlating this notion of motivation (as explained through self-efficacy) and trust, if we refer to the definition of trust put forth by Mayer et al. [43], they define it as "*the willingness of a party to be vulnerable to the actions of another party based on the expectation that the other will perform a particular action important to the trustor, irrespective of the ability to monitor or control that other party*" (p. 712). During a user's interaction with a technological artifact, the user is both vulnerable and cannot monitor how the system would behave, but if they feel that (a) using the system would fulfill a certain purpose and (b) that they themselves have the inner capability to complete a certain task, this would lead to an interaction with the technical artifact. Therefore, we opine that higher the CSE of an individual, the higher the trust they would place in the system and as a consequence, they would feel less vulnerable. Consequently, we hypothesize that:

H1. User self-efficacy has a positive effect on their trust towards using technology.

3.2 Willingness

We define willingness as an individual's reflection of positive or negative feelings, evaluating pros and cons and considering risk and incentives associated with performing a given action when using a system. Psychological research has also demonstrated that human behavior is goal directed [17]. Study of such a goal directed behavior can be explained using Theory of planned behavior (TPB) [1]. The underlying principle of this theory is that intention of an individual is the best predictor of their behavior. This intention is in turn determined by three constructs namely attitude, subjective norm and perceived behavioral control. Essentially, a person will perform behaviors if:

- Advantages of success outweigh the disadvantages of failure (behavioral attitude).
- Other people with whom they are or interact think they should perform the behavior (subjective norm).
- Have sufficient control over factors which influence success or ability to perform the behavior [perceived behavioral control (PBC)].

Prior research by Belanche et al. [3] on understanding user trust in public e-services found out that evaluation of outcome expectations, both from the service (performance expectations) and what an individual would achieve using an e-service (individual expectations) play an important role in fostering trust. Outcome expectations are also an important pre-cursor for technology usage and acceptance [8]. Studies have also shown trust to be a key factor in deciding whether users will continue to interact with and use the system [18,44]. Therefore, we assert that after evaluating pros and cons and considering risk and incentives associated with their interaction, if a user feels that their interaction will have a positive outcome, their trust with regards to the technology that they are interacting with would be well placed. Therefore, we hypothesize that:

H2. The higher the willingness or outcome expectations associated with performing an action, the greater the trust towards the technology.

3.3 Competence

We define competence as the ease of use associated with the use of a system in that it is perceived to perform its tasks accurately and correctly. While trying to understand the degree to which human operators would trust automated control of systems, Muir and Moray [49] came up with the concept of competence and defined it as the extent to which the technology performs its functions properly. On similar lines, Constantine [9] note that competence means that the system is capable of doing what the user needs it to do, performs reliably and delivers accurate results. He also states that in order for the system to be competent or in order for the user to perceive the system as being competent, it must perform with sufficient speed and meet user's needs with respect to timeliness.

The competence of a system can be explained through the technology acceptance model (TAM) [10], specifically the perceived ease of use determinant of TAM. According to Davis [10], a user would interact with and accept the technology when they perceive technology to be useful, easy to use and performing as it says. When the user perceives that technology is easy to use, their PBC, according to theory of planned behavior [1], would also be higher which means that it is likely that they will use and interact with technology and higher the competence that a user would assign to a system, greater would be the trust of the user with that system [4,45]. Therefore, this leads to our third hypothesis:

H3. The higher the competence associated with the use of a system, the greater the trust of the user with that system.

3.4 Benevolence

In a conventional sense, benevolence has been understood as the perceived level of courtesy and positive attitude a trustee displays towards the trustor [43]. It is also viewed as the trustee being genuinely interested in the trustor's welfare without any ulterior motives and is motivated to seek joint gain [12]. We define benevolence as a user's perception that a particular system will act in their best interest and that most people using the system share similar social behaviors and values.

It can be further understood through the lens of social response theory [47]. According to this theory, when people interact with technology, they view it as a social actor and their relationship with it is governed by same social rules which would govern an interpersonal relationship. Hence, people look for cues to associate their interaction with technology. They expect certain human like behavior from technology i.e. the technology would act in their best interest and not try to deceive them [37,47]. When individual's perceive that technology would help them and act in their best interest, there is a likelihood of higher continued use and fostering a higher level of trust with that technology [4,36]. Synthesizing these arguments, we hypothesize:

H4. There exists a positive relationship between perceived benevolence of a technological artifact and trust.

3.5 Predictability

We define predictability as the belief of an individual that systems actions (whether good or bad) are consistent enough that one can forecast them and it will help the user to perform a desired action in accordance with what is expected. This can be understood based on Expectation confirmation theory which posits that every action is associated with certain expectations and when these expectations are met, it leads to satisfaction [54]. Though the theory was initially proposed in a marketing context, it has been adopted in a technological context to study user adoption and continual use of technology [27]. If a user can predict the use of a system, then it is likely that they would use it and if the use of the system matches their expectations, they would not only be satisfied but also perceive the system to be trustworthy [19]. This leads us to our fifth hypothesis:

H5. The greater the predictability of a technological artifact, the higher the level of the trust associated with it.

3.6 Honesty

Honesty can be defined as a secure belief of an individual that the other person makes good faith agreements, tells the truth, and fulfils promises [6]. Since people can enter into relationships with technology, they expect it to work towards their good, adhere to a certain set of standards and not betray them. If a user is confident that the technological artifact they are dealing with exhibits a certain level of sincerity and is genuine, then it is perceived to be honest which will affect user trust. For instance, while using electronic payment services such as PayPal for sending or receiving money, a user can be rest assured that their money is being channeled through a trustworthy, reliable source that is sincere and genuine (which basically means that PayPal as an organizations exists and is not just a spoof) and in case, there are issues with regards to money transfer, it would be well taken care of by the customer services team of PayPal.

Thus, there exists a positive relationship between user perception of honesty with regards to technology/software and subsequent trust manifestation. Honesty can be best understood through the Source credibility theory, according to which people are more likely to be persuaded and follow a course of actions if the source is credible [28], which in this example was PayPal. Through this lens, if a user perceives an application or a software to not be trustworthy, it is highly unlikely that they would act on the advice or information provided by that software. This leads us to the following hypothesis:

H6. The higher the level of perceived honesty of a technological artifact, the higher the level of trust associated with it.

3.7 Reciprocity

In his seminal work, Gouldner [21] put forth that reciprocity involves a give and take relationship and asserted that people are helpful and kind to those who are helpful and kind to them. We build on this work and define reciprocity as the degree to which an individual sees oneself as a part of a group. It is built on the principle of mutual benefit, feeling a sense of belonging and feeling connected. Psychological research has demonstrated that if people feel helped, they respond in kind [26]. Within the context of HCI, research has demonstrated that people have a friendlier attitude towards a system when they have received some help from it. If people feel that a system has been helpful towards them, they respond in kind by deciding to adopt and continually use it and develop a symbiotic relationship with that system [14,47]. This leads us to our final hypothesis:

H7. The higher the level of perceived reciprocity associated with a technological artifact, higher would be the level of trust associated with it.

4 Method

A semi-structured questionnaire was chosen to measure user trust levels with the Estonian I-voting service. The main reason behind choosing this artefact was that despite Estonia being a digitally advanced and a tech savvy EU member state and the rate of technology uptake and new technology diffusion being higher in the country when compared to other EU countries [60], trust levels of the citizens with the I-voting service are low [65]. Despite its first use in parliamentary elections in 2005, there have been issues with regards to the design of the I-voting system and questions raised as to whether it should be implemented or not [68]. A report published by Heiberg et al. [25] has identified several inconsistencies, software bugs and audit deficiencies with the electronic voting service.

The aforementioned issues, along with the fact that trust plays an important role in maximizing voter turnout in an electronic environment, and that the next set of elections in Estonia are to be held in 2017 [65], it is important that any underlying trust issues with the I-Voting system be systematically analyzed. From a technological standpoint I-voting is also labelled as an emerging technology which will continue to develop in the years to come. Several countries such as Germany, Austria, Norway etc. have expressed a desire to use Internet voting but have rejected its adoption, primarily due to trust issues [20]. Therefore, trust issues with an I-voting service need an in-depth exploration. To the best of our knowledge, this is one of the first studies to analyze user trust levels with the Estonian I-voting service.

4.1 Participants

The data for the survey was collected with the help of Republic of Estonia's Information Systems Authority[1], a government body coordinating development and administration of the information systems of Estonia from April 2016-January 2017. We also enlisted help of local Estonian public universities and professional organizations to disseminate our research. We used LimeSurvey as a tool for making our questionnaire and collecting data. The questionnaire was constructed in both English and Estonian.

A total of 227 responses were obtained out of which 207 had used the Estonian i-voting service before. Hence, these respondents were chosen for our analysis since we were interested in understanding user trust levels with the Estonian i-voting service of people who have used it before. Totally, 122 females

[1] https://www.ria.ee/en/.

(53.74%) and 105 males (46.26%) took part in the survey. Most of the respondents (35.68%) were between the age of 18 and 27 years. This was followed by 32.60% and 22.47% for age groups 28–37 and 38–47 respectively.

4.2 Apparatus

All the survey measures were adopted from well-established prior studies. Scales measuring motivation and willingness were adapted from Compeau and Higgins [8]. Competence, benevolence and honesty were derived from McKnight et al. [45]. The work of Gefen and Straub [19] was referred to for adapting predictability. Each of the two measures for reciprocity were derived from Wasko and Faraj [71] and Kankanhalli et al. [31]. To collect data using these scales, we used 5 point likert scales in our questionnaire, where 1 indicates strongly disagree and 5 indicates strongly agree.

4.3 Procedure

The data obtained was analyzed using PLS-SEM and the main reason behind choosing this technique was because our main goal is theory development rather than theory testing, for which other covariance based SEM approaches are more appropriate [22]. Secondly, the objective of our study was to empirically assess the suitability of the human computer trust model [67] in a HCI context and assess whether the exogenous variables in the model explain the endogenous latent variable of interest which is trust. Such an approach is predictive in nature since we wish to empirically explain the variance in trust by identifying its driver constructs. Thus, the predictive nature of the study coupled with the main goal being theory development justify use of PLS-SEM for data analysis [23].

5 Results

It has been rightly pointed out by Hair et al. [23] that hypothesis testing involving structural relationships among constructs will only be as reliable or valid as the measurement model which is explaining these constructs (p. 45). Within the trust literature, Söllner and Leimeister [64] have pointed out measurement model mis-specifications wherein researchers have modelled reflective constructs as being formative and formative as being reflective. They further argue for a more systematic modelling approach to trust based on sound theory. In line with this, we use prior research done on trust by Lankton and McKnight [36] and McKnight et al. [44] and model trust as being a reflective endogenous construct conceptualized through 7 exogenous constructs.

PLS-SEM involves assessment of the outer measurement model that explains relationships between the exogenous latent variables and their indicators and an inner structural model which explains relationships between the endogenous variable of interest with its exogenous constructs. These are explained as follows:

5.1 Evaluation of the Measurement Model

An initial analysis in SmartPLS revealed certain outer loadings of the exogenous constructs to be below 0.7. We retained only those indicators that had outer loadings above 0.6 and removed all below 0.4 [23]. Finally, 20 measures were dropped and final instrument had 22 measures in total across exogenous and endogenous constructs. The evaluation of measurement model involves assessment of internal consistency [Cronbach's alpha (CA), composite reliability (CR)], convergent validity [indicator reliability, average variance extracted (AVE)] and discriminant validity [23]. Regarding internal consistency, both CA & CR values should be between 0.60 and 0.90 [22]. Barring willingness for which the CA value was 0.574, all other latent variables were between 0.60–0.90. According to Hair et al. [23], such a low value can be attributed to the fact that CA values are sensitive to the number of items in the scale and generally tend to underestimate the internal consistency reliability (p. 111). Even though our value is not considerably below the 0.60 threshold, one should generally not rely on CA values alone and also report CR values [22]. As can be seen from Fig. 2, the CR values for all latent variable well exceeded the recommended threshold of 0.80 [23]. Since both the CR & CA values exceed the threshold, this establishes internal consistency reliability of the measures used in our study.

Latent Variable	Indicators	Convergent Validity			Internal Consistency Reliability	
		Loadings	Indicator Reliability	AVE	Composite Reliability	Cronbach's Alpha
		>0.70	>0.50	>0.50	0.60-0.90	0.60-0.90
MOT	MOT 1	0.864	0.746	0.741	0.851	0.650
	MOT 2	0.858	0.736			
WIL	WIL 1	0.620	0.384	0.574	0.842	0.751
	WIL 2	0.767	0.588			
	WIL 3	0.804	0.646			
	WIL 4	0.823	0.677			
COM	COM 1	0.825	0.680	0.665	0.856	0.748
	COM 2	0.832	0.692			
	COM 3	0.789	0.623			
REC	REC 1	0.819	0.671	0.689	0.815	0.548
	REC 2	0.840	0.706			
PRED	PRED 1	0.858	0.736	0.749	0.857	0.665
	PRED 2	0.873	0.762			
BEN	BEN 1	0.809	0.654	0.631	0.837	0.707
	BEN 2	0.781	0.610			
	BEN 3	0.792	0.627			
HON	HON 1	0.854	0.729	0.713	0.882	0.799
	HON 2	0.857	0.734			
	HON 3	0.822	0.676			
TRU	TRU 1	0.813	0.661	0.702	0.876	0.788
	TRU 2	0.850	0.722			
	TRU 3	0.850	0.722			

Fig. 2. Results summary for reflective measurement of trust

Concerning convergent validity, indicator reliability and AVE values need to be greater than 0.50 [23]. As can be observed from Fig. 2, only one indicator namely WIL1 for willingness which asks the respondent to rate their agreement with the statement "*If I use i-voting, it will help me be more efficient and organized during the voting season*" has an outer loading of 0.620 and an indicator reliability of 0.384, but based on guidelines set by Hair et al. [23], this was not dropped as from a theoretical perspective, its inclusion is justified based on the premise that the Estonian i-voting service was designed and implemented not just to ease the overall voting processes in the country but to also make it easy for Estonians to vote from anywhere in the world making it more efficient for them to be involved with the democratic process of the country [65]. Further, if we observe the AVE values for Willingness, it exceeds the threshold of 0.50. The AVE values for all latent variables are above 0.50, thus establishing convergent validity for the study.

Concerning discriminant validity, which is the extent to which a construct is distinct from other constructs by empirical standards, two approaches, namely the Fornell-Lacker criterion and cross-loadings approach are to be reported [23]. For adequate discriminant validity, the Fornell-Larcker criterion requires the square root of each construct's AVE to be greater than its correlation with each of the remaining constructs [15]. If we observe the square root of these values in Table 1 as shown by the bold values in the diagonal, our results meet this requirement. Secondly, regarding cross-loadings, discriminant validity is established when an indicators cross-loading on an assigned construct is higher than all of its cross-loadings with other constructs [23]. If we observe Fig. 3, all the cross loadings values are highlighted and satisfies this requirement as well. Therefore, our instrument satisfies requirement for internal consistency reliability and convergent and discriminant validity.

Indicators	Benevolence	Competence	Honesty	Motivation	Predictability	Reciprocity	Willingness	Trust
BEN01	0.809	0.662	0.612	0.559	0.580	0.502	0.426	0.612
BEN02	0.781	0.606	0.480	0.568	0.547	0.411	0.291	0.565
BEN03	0.792	0.542	0.523	0.489	0.456	0.455	0.275	0.604
COM01	0.628	0.825	0.638	0.533	0.627	0.561	0.420	0.673
COM02	0.662	0.832	0.627	0.611	0.612	0.523	0.428	0.657
COM03	0.567	0.789	0.603	0.533	0.577	0.465	0.381	0.636
HON01	0.556	0.627	0.854	0.577	0.608	0.439	0.421	0.700
HON02	0.633	0.688	0.857	0.593	0.602	0.513	0.480	0.695
HON03	0.532	0.619	0.822	0.558	0.572	0.455	0.376	0.664
MOT01	0.577	0.561	0.570	0.864	0.542	0.498	0.304	0.601
MOT02	0.590	0.620	0.604	0.858	0.645	0.511	0.468	0.588
PRED01	0.516	0.628	0.576	0.580	0.858	0.459	0.373	0.602
PRED02	0.630	0.657	0.641	0.612	0.873	0.461	0.367	0.635
REC01	0.411	0.496	0.448	0.441	0.445	0.819	0.275	0.476
REC02	0.541	0.555	0.473	0.530	0.438	0.840	0.351	0.504
WIL01	0.227	0.295	0.350	0.194	0.228	0.227	0.620	0.256
WIL02	0.326	0.380	0.420	0.303	0.309	0.267	0.767	0.348
WIL03	0.347	0.402	0.395	0.382	0.365	0.362	0.804	0.398
WIL04	0.350	0.430	0.376	0.432	0.370	0.280	0.823	0.415
TRUST01	0.619	0.637	0.591	0.538	0.567	0.512	0.342	0.813
TRUST02	0.640	0.686	0.695	0.591	0.616	0.500	0.429	0.850
TRUST03	0.623	0.695	0.749	0.603	0.611	0.478	0.419	0.850

Fig. 3. Cross loadings of indicators with corresponding constructs

Table 1. Latent construct correlations and square root of AVEs.

	BEN	COM	HON	MOT	PRED	REC	TRU	WIL
BEN	**0.794**							
COM	0.760	**0.816**						
HON	0.680	0.764	**0.844**					
MOT	0.678	0.686	0.682	**0.861**				
PRED	0.664	0.742	0.704	0.689	**0.861**			
REC	0.576	0.634	0.556	0.586	0.532	**0.830**		
TRU	0.749	0.804	0.813	0.691	0.715	0.591	**0.838**	
WIL	0.418	0.502	0.505	0.447	0.427	0.378	0.475	**0.758**

5.2 Evaluation of the Structural Model

Addressing the issue of collinearity i.e. to examine if the predictor variables are correlated to each other is important when evaluating the structural model [22]. This is done by examining the variance inflation factor (VIF) values. Upon examination, the VIF values for benevolence, competence, honesty, motivation, predictability, reciprocity and willingness were 2.765, 3.950, 2.976, 2.589, 2.734, 1.831 and 1.420 respectively, which are below the threshold of 5 [23]. Therefore, there is no issue of multi-collinearity in our model. Secondly, we use coefficient of determination R^2 to assess model explanatory power. The R^2 is interpreted in the same way as it would be in a conventional regression analysis [23]. In our study, both the R^2 and the R^2 adjusted values are 0.768 and 0.760 respectively. Generally, values of R^2 above 0.7 are substantial or strong [22,23]. Thus, based on this, our model has a good predictive power, which essentially means that the exogenous variables predict the endogenous variable (trust) with a high degree of accuracy.

To test our proposed hypotheses and analyze the statistical significance of the path coefficients, we performed nonparametric bootstrapping with 5000 subsamples and 207 cases (the sample size of the current study) at a significance level of 0.05 [23]. As can be seen from Table 2, the only hypothesis which are statistically supported are H3 (Competence→Trust), H4 (Benevolence→Trust) and H6 (Honesty→Trust). To further assess empirical validity of the results, we used the blindfolding method and report the Q^2 value, which is a measure of predictive relevance [22]. According to Hair et al. [23], blindfolding procedure is a re-sampling technique that systematically deletes and predicts every data point of the indicators in the reflective measurement model of endogenous constructs (p. 222). Using the cross validated redundancy approach, the Q^2 value which we obtained for trust was 0.502. Q-square values above zero suggest that the model has predictive relevance for a certain endogenous construct [23].

Table 2. Significance testing results of structural model path coefficients

Hypothesis	Path coefficients	t values	p values	Sig ($p < 0.0.5$)
H1	0.056	0.909	0.363	No
H2	0.009	0.207	0.836	No
H3	0.248	2.951	0.003	Yes
H4	0.189	2.775	0.006	Yes
H5	0.078	1.223	0.221	No
H6	0.376	5.369	0.000	Yes
H7	0.039	0.739	0.460	No

Therefore, not only do we provide bootstrapping measures, but we also go one step further in reporting the predictive relevance through the blindfolding approach. Based on our results, we can state that the constructs which are associated with the significant hypothesis in our model accurately predict trust.

6 Discussion

This study has explored the role of trust in HCI using Estonian I-voting service as the artefact. To the best of our knowledge, this is the first study to systematically analyze user trust levels when they interact with this online voting service. The data from this study has helped us evaluate certain aspects of the socio-technical model of trust, while certain hypotheses were not statistically significant.

As can be observed from Table 2, the relationship between motivation (operationalized through technology self-efficacy) and trust is statistically not significant. Even though self-efficacy predicts motivation [61] and we hypothesized that higher levels of self-efficacy are associated with higher levels of trust, this was not the case in our research. This does not mean necessarily that there exists no relationship between these constructs in general. We argue that such a limitation may only be specific to our study. Since the current study was carried out with the Estonian I-voting service within Estonia, which is not just one of the most tech savvy countries in Europe but the technology diffusion and the reliance of people on technology to carry out tasks is much higher when compared to other European countries. For instance, the number of National Digital IDs, a mandatory national card used by the citizens of the country to access Estonia's e-services has exceeded one million and nearly 95% of the Estonian population is used to declaring their taxes online [65]. The Estonian population is used to using the internet for various purposes and people's use of e-services offered by the government is considerably high. With such high technological diffusion and everyday reliance on technology, the statistically non-significant relationship between motivation (operationalized through self-efficacy) and trust is not surprising. If we recall, self-efficacy is an individual's inherent belief in themselves in whether or not they feel that they can execute a technologically oriented task [8]. If people are used to using technology on a daily basis, then immaterial of their trust levels with the technology, their innate capacity to overcome challenges using such technology would be high, which is why there is a negative relationship between motivation and trust.

The statistically non-significant relationship between Willingness and Trust (H2) and predictability and trust (H5) can also be explained on similar lines. H2 was operationalized based on how willing a user is to interact with and place trust on an artefact based on the consequences of their interaction [8]. Essentially, if a user feels that there can be positive outcomes associated with the interaction, their trust levels would be high. Similarly, H5 was concerned with assessing user's certainty or their belief of how they expect a system to behave and whether or not they can foresee or predict the actions of the system. The common denominator in how both these hypothesis were operationalized was that the user should either be able to foresee and predict tangible consequences associated with interacting with an artefact or assess if the technological artefact is performing a desired action in accordance with what is expected. The results of the study indicated that such an operationalization does not hold true in the Estonian context since citizens are used to interacting with numerous e-services on a daily basis and whether or not they can expect the outcome beforehand or predict how the service would operate is not related to how much they would trust the service. Since the technology uptake and reliance on technology on a daily basis is much higher in Estonia when compared to other EU countries, future research could benefit from using alternative ways to conceptualize willingness and predictability and see if these indicators are relevant in a user technology interaction.

Finally, the relationship between reciprocity and trust (H7) was also statistically non-significant. To our knowledge, the existing literature on conceptualizing reciprocity has done so using social capital theory. Since social capital is fundamentally how people interact with each other, it has been adopted to explain technology mediated interactions [31,71]. In the current context, the results of the study demonstrated that such a conceptualization does not hold true as social capital theory cannot be used to explain user interaction with the Estonian I-voting service since it is an example of user technology interaction and not technology mediated interactions. This result was expected since the human computer trust model was proposed to study human to human interaction mediated through technology and not user technology interactions. Hence, based on the results of the current study, the current conceptualization of reciprocity cannot be used to study human-technology interactions and future studies involving the use of the current model should take this into consideration.

Our results demonstrate that it is not so much the social aspects of a user interaction but the focus on technological attributes which tell whether or not the Estonian I-voting system is perceived as trustworthy. For instance, our results demonstrate that what was important to the users was how competent and efficient is the I-voting service (competence), if the I-voting service was designed with the user's best interest in mind and will always operate in such a way (benevolence) and finally if the online voting service is honest in its interaction with the user. This also answers research question two which was aimed at understanding which attributes of the model hold true in case of user technology interactions. It would be interesting to see if these results could be generalized to other e-services which are used in Estonia and see if they still hold fit.

6.1 Study Limitations

Our study is not without its own limitations which can be directions for future research. As has been rightly put forth by Kyriakoullis and Zaphiris [35] that it is important to pay attention to cultural aspects when studying a user interaction with technology. They further put forth that "*understanding cultural values is essential for the design of successful and widely accepted user interfaces*". In our study, we did not take into consideration the impact of culture on trust and user acceptance of the I-voting service. However, future research involving the use of this model could take into account such cultural and ethnic considerations keeping in mind that these differences impact user trust and their desire to continually use technology in different ways [69]. These studies can either be intercultural wherein trust levels of people within a particular culture are studied and compared or cross-cultural wherein trust levels within different cultures are examined simultaneously.

Secondly, our research was situated in Estonia, a tech-savvy EU member state. Since trust research is contextual and results can vary depending on the context in which the research is situated [11,40], future research should take into account other contexts in which citizens of the countries are not used to using technology on a regular basis and then see if there exists a positive correlation between attributes such as self-efficacy, willingness and predictability with trust.

Finally, we did not control for citizens trust with the government and the impact which that might have with their use of I-voting service. Future research can benefit by including citizen government relationship as an attribute to measure user trust with the I-voting service or e-services in general.

7 Conclusions

Based on well-established social psychological theories, this study has empirically assessed and refined human computer trust model [67]. Since the model was initially proposed to study trust in technologically mediated interactions, the data from this study has helped us evaluate certain aspects of this model and we empirically demonstrated which attributes of the model hold fit in the case of user technology interactions. Even though the proposed indicators explain a significant amount of variance of our dependent variable trust in our structural model, future research should work on identifying more reflective indicators and test whether or not they enrich our model and can be used to extend and refine it. There have been recent attempts made by Söllner et al. [63] and Lankton and

Mcknight [37] to propose more trust in technology attributes but they also call for more research on the topic.

As technology becomes more autonomous, ubiquitous and its nature becomes increasingly non-deterministic and stochastic, it becomes more important to study trust since it is crucial for ensuring its acceptance and continual use [37,63,72]. It would be important to see how the current model can be used in different contexts to study user interactions with artefacts that fit this criteria. Future research should therefore focus on identifying more trust in technology attributes and developing robust psychometric instruments to measure trust as this will have enormous implications for both research and practice.

Appendix:

Further details regarding Data, Measures used for the survey research and questionnaire are available online at: https://goo.gl/PTQBEj

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