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ORIGINAL ARTICLE

Exploring the impact of trust information visualization on mobile application usage

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Abstract Trust allows people to live in a risky and uncertain situation by providing the means to decrease complexity. It is the key to decision making and engaging in usage. Visualizing trust information could thus leverage usage behavior and decisions. This article explores the impact of trust information visualization on mobile application usage with a three-stage experiment conducted in both Finland and China (1) by studying users' opinions on the importance of mobile applications, (2) by evaluating the impact of a trust indicator on mobile application usage, and (3) by evaluating the impact of a trust/reputation indicator on mobile application usage. Although the results achieved in this study for Finland and China showed small differences on usage willingness and remarkable difference on trust information check willingness, both countries indicated that visualizing the reputation value of an application and/or the individual trust value of a user can assist in mobile application usage with different importance rates. In addition, the article discusses possible reasons for the difference in impact in Finland and China, other impact factors related to mobile application usage, and implications of our experiments with regard to a trust management system for mobile applications.

Keywords Trust · Reputation · Trust/reputation visualization · Human–computer trust interaction · Mobile application

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1 Introduction

Mobile devices have evolved into an open platform to execute various applications. A mobile application is a software package that can be installed and executed in mobile devices. An example of such an application is a mobile web browser to access the Internet. Generally, mobile applications developed by various vendors can be downloaded for installation. This situation means that there are a number of mobile applications with similar functions available for users. The future market could thus be competitive. For this reason, the trustworthiness of the mobile application is a central issue impacting not only user selection and usage but also the ultimate success of the application.

Trust is a multidimensional, multidisciplinary, and multifaceted concept, for which there are various definitions, many of which can be found in the literature. Common to these definitions are the notions of confidence,

belief, and expectation on the reliability, integrity, ability, and other such characteristics of an entity [63]. Definitions of trustworthiness in mobile applications relate to their dependability, security, and usability [4], as well as popularity [65]. In this paper, our working definition of user trust in a mobile application is the user's belief in the application being able to fulfill the expected task. From the public trust perspective, the reputation of the mobile application is derived from direct and indirect knowledge or experiences. In our study, public trust (i.e., reputation) is defined as the public belief in a mobile application that could fulfill a task according to the expectations of many users. However, user trust in a mobile application is highly subjective. It is built up over time and changes with application use due to the influence of many factors.

Through practical usage, users make decisions about the trustworthiness of mobile applications. A user decision is generally required during practical consumption of a mobile application. For example, a user decides whether it is safe to conduct an important task with the mobile application or whether it is worth the risk of trying. Mobile users are not given any cue that can help their usage decision. Trust obviously plays an important role in application consumption and usage, as it helps users overcome perceptions of uncertainty and risk. Trust also helps them engage in trust behaviors (i.e., the actions of a trusting subject to depend on or make her/him vulnerable to a trusting object) [36]. Numerous researchers have found a positive correlation between trust and use [30, 39, 40, 55]. Some researchers have conceptualized trust as a behavior [1, 15, 21]. Previous research has also confirmed a strong correlation between behavioral intentions and actual behavior, especially for human–software system interaction [54, 60]. However, few existing studies explore the impact of visualizing trust information in the context of mobile application usage [28, 33, 38, 45].

This article studies the impact of visualizing trust information on mobile applications. We hypothesize that visualizing trust information could leverage usage decision. We validate that displaying the reputation value of a mobile application and/or the individual trust value of a user could enhance the user's ability to perform appropriate actions in various usage contexts. Detailed trust information about how trust/reputation values are generated can be accessed in an additionally specific way during application execution for usability. Our validation is based on a three-stage experiment conducted in both Finland and China.

In this article, we first briefly review human–computer trust interaction. We then introduce our research question and method followed by experimental details and results. Thereafter, we conclude our findings and further discuss possible reasons for different effects in two countries, other impact factors related to mobile application usage, and the implications of our experiments with regard to a trust management system for mobile applications.

2 Human–computer trust interaction

This section briefly reviews issues related to human–computer trust interaction, which include UI design techniques for trust, interrelationships between trust and use, trust information notification and visualization, trust and reputation mechanisms, and other related work.

2.1 Notion of trust

Trust is a complicated notion that has been studied by many researchers in various domains. It is firstly a social phenomenon. The concept of trust has been studied in disciplines ranging from economics to psychology, sociology to medicine, and information science to computer engineering. Researchers have defined trust in many different ways, which often reflect the paradigms of particular academic disciplines. For example, Grandison and Sloman [22] held the opinion that trust is a qualified belief by a trustor with respect to the competence, honesty, security, and dependability of a trustee within a special context. Alternatively, Corritore et al. [11] stated that online trust is an attitude of confident expectation in an online situation of risk that one's vulnerabilities will not be exploited. In a multi-agent system, trust is a subjective expectation that one agent has about the future behavior of another agent [37]. From a software engineering perspective, trust is accepted dependability [4]. In an ad hoc network, trust is the reliability, timeliness, and integrity of message delivery to a node's intended next-hop [31]. The current paradigm for trusted computing systems holds that trust is a property of a system. Trust can be formally modeled, specified, calculated, and verified. Trust itself is an assessment made by users based on how well the observed behavior of the system meets their own standards or expectation [13, 66]. In this article, we derived our understanding of trust in mobile applications, which entails crossing multiple disciplines, as defined in the introduction.

2.2 UI design for trust

Trust is an integral component in many types of human interaction, allowing people to act under uncertainty and with the risk of negative consequences [3]. Researchers in human–computer interaction (HCI) and human factors have recently studied trust in an online context, but few researchers have explored the role of trust in the mobile application domain. The realization that design can affect

the trust of a user has had implications for user interface (UI) design, web sites, and interactivity in general [41].

Trust can be affected by a wide range of cues. These cues range from design and interface elements to perceived website credibility and also include the extent to which the technology is perceived and responded to as a social actor [11]. For example, Wang and Emurian [61] identified types of trust cues, including interface design features, structure design (e.g., the look and feel of the site), content design (e.g., the inclusion of security and privacy policies seals of approval or third-party certificates), and social cue design (e.g., photographs and other social presence indicators). In addition, trust is influenced by perceived integrity and expertise, predictability or familiarity of content, and reputation [8, 10, 35].

Recent research focused on the cues that convey trustworthiness to users. Several studies illustrated how interface design can give a cue of trust or signal trustworthiness [11, 49]. Other studies identified the following cues that have been found to have a positive impact on trustworthiness perceptions: ease of navigation or ease of access [42], good use of visual design elements [26], the presence or absence of visual anchors, interpersonal cues or prominent features, such as a photograph, video/audio, avatar, or trust seal [20, 43, 48, 56], which strongly depend on context variables, individual differences, and personality [46, 47, 58], freedom from small grammatical and typographical errors [19, 42], an overall attractiveness and professional look [27, 56], ease of searching [42], professional images of products [42], and ease of carrying out transactions [11, 32, 42]. Studies have been inconclusive on the value of third-party trust logos and seals of approval [11, 52]. Users appeared to not notice or care about these logos and seals [42, 52].

Social cues are particularly important in the design of trustworthy websites or user interface. One social cue includes appropriate graphics and photographs that can add to a sense of social presence and inclusion, while inappropriate mission statements or alienating language can have the opposite effect [56, 61]. Research on using images of website personnel reveals contradictory results: Some studies found such images were a positive cue [18, 42, 58], while others found them to be neutral or negative [47]. Another social cue is dialogue. An implementation in an embodied conversation agent was demonstrated to have a positive effect on trust for users with a disposition to be extroverts [9]. A study on real-time interactivity, excluding voice, also showed increased judgments of friendliness and the trustworthiness of an online salesperson [7]. However, other researches revealed that online word-of-mouth systems could affect user trust in e-commerce, where users can rate the products offered for sale [5].

Other researchers have found that the quality and quantity of computerized information influence user trust and satisfaction [28]. Corritore et al. [11] reported that trust is also affected by the information content. Providing content that is appropriate and useful to the target audience has thus been identified as a strong trustworthiness cue [53]. Positive cues include conveying expertise, providing comprehensive information, and projecting honesty, lack of bias, and sharing values between the website and user [19, 29, 42]. In e-commerce, cues that affect user trust include company information, range of merchandize, branding, promotions, security, fulfillment, and customer service [11, 19, 32, 42, 47]. In addition, Herlocker et al. [23] studied the influence of explanations on user acceptance of automated collaborative filtering (ACF) systems. Cramer et al. [12] showed that explaining to the user why a recommendation was made increased acceptance of the recommendations. Recent research on an automated recommender suggests that trust can be increased by a conversational interface and disclosure of what the recommender system knows about its users [11, 70].

However, previous studies have not considered how to confer computational trust values to the users and how this information could impact trust.

2.3 Trust and use

Previous research has shown that trust and use have a tight relationship. The Theory of Reasoned Action posits that beliefs lead to attitudes, which lead to behavioral intentions, which subsequently lead to the behavior itself [17]. Numerous researchers have conceptualized trust as a behavior, which has been validated in work collaboration and social communications [1, 15, 21]. Prior research has also confirmed a strong correlation between behavioral intentions and actual behavior, especially for software system usage [54, 60]. Muir found a positive correlation between trust and use [39, 40]. The relationship between trust and interaction behavior is obvious, as usage through human–computer interaction implies trust. Lee and Moray found that trust in a system partially explained system use, but other factors (such as the user's own ability to provide manual control) also influenced system use [30]. Although use implies trust, current literature still lacks study on the impact of visualizing trust information on use, especially in the context of mobile applications.

2.4 Trust information notification and visualization

Trust information notification and visualization is highly related to the work presented in this paper. Notification systems attempt to deliver current, important information to users efficiently and effectively without causing

unwanted distraction to ongoing tasks [34]. However, some issues remain unexplored in this area. McCrickard et al. commented that the effects of incoming notifications on ongoing computing tasks have been relatively unexplored [34]. Notification without usage interruption still lacks investigation, especially for mobile and ubiquitous devices that include a small display element. Antifakos et al. [2] conducted experiments to show that displaying confidence information increases user trust in a system in various contexts classified by criticalness. Rukzio et al. [51], however, proved that the user needs slightly more time and produces slightly more errors when the system confidence is visualized. The contradictory results implied that the visualization of system confidence seems questionable or works differently in different situations.

2.5 Other related work

The literature has not comprehensively studied trust and reputation information visualization, though trust and reputation mechanisms have been proposed in various fields, including ad hoc networks, peer-to-peer systems, grid and pervasive computing, web services, and e-commerce [64]. It is commonly accepted that trust can be modeled in a mathematic measure and its value can be calculated [66]. In many existing web services (e.g., eBay.com and Amazon.com), reputation values (mostly on a Likert scale) are displayed based on rating to assist user decision. However, few previous works studied the mutual effects of visualizing both individual and public trust (i.e., reputation) values to the mobile application users during its execution.

Other factors may also influence trust in HCI. Cultural factors are also important variables affecting trust and its development in HCI [6]. It was found that Japanese people have a generally low level of trust compared to Americans [62]. Karvonen found that Finnish consumers are the most cautious and Icelandic consumers are the most trusting in Nordic countries in e-commerce [25]. Human nature is another influential factor of the trust in HCI. Deutsch [14] found a significant correlation between trust and personal predisposition. Emotion and mood could also influence trust judgment [16].

Regarding the methodology applied in past research, many current e-commerce trust design guidelines are based on surveys and interviews for capturing the interface elements or cues that they currently interpret as trustworthiness signifiers [49]. This approach provides important practical guidance to user interface designers about interface elements that increase perceived trustworthiness, for example, in a recommender system [45]. In the work presented in this article, we use both a self-developed toolkit and interviews to investigate the benefit of using visual elements of trust information and pursue design guidelines of a trust management system for mobile applications.

In summary, much research has been conducted regarding user interface design for human–computer trust establishment and improvement, mainly for web sites and in e-commerce. This prior work left room for further studies on the impact of trust information visualization on usage behaviors and, in particular, on how to provide trust information for mobile users. In our work, we use a trust indicator to indicate an individual trust value and a trust/reputation indicator to indicate both the individual trust and reputation values. The indicators are interface design elements that provide trust information cues in a mobile application trust management system [67, 69]. The individual trust value could become the valuable credibility for the contribution of a user (e.g., his/her rating) to the reputation of a mobile application. In addition, the individual trust and reputation values could serve as credibility for each other. No previous research has investigated the mutual impact of these two pieces of information on users, which is one of our research targets. The above impact could also be affected by region and culture (e.g., western and eastern cultures) or context (e.g., the importance of the mobile application), which is explored in our study.

3 Method

3.1 Research questions

User trust in a mobile application is built up over time and changes with application use due to the influence of many factors. We developed a system to estimate individual trust based on the usage behaviors of a user (e.g., usage behavior about normal usage statistics, reflection behavior related to application performance and user experience, and correlation behavior regarding similarly functioned applications) [65, 67, 69]. We achieved an individual trust model by mathematically formalizing trust behavior measures that were investigated in a large-scale user study [68]. The individual trust is calculated by the mobile device of the user based on trust behavior observations.

The reputation value of an application is generated by aggregating the individual trust and ratings. It is issued by a reputation service provider, designed by Yan et al. [69]. We use a number to indicate the individual trust and reputation values, respectively. Their values range from 0 to 1, representing the range of full distrust to full trust. We use a rectangle bar to indicate the individual trust value and a trapezoid bar to indicate the reputation value in our experiments. The individual trust value is presented by the trust indicator. The trust/reputation indicator presents both values.

We also assumed that detailed trust information is available through an additional access point, either from a device menu or by touching the indicator or via a shortcut key/icon, because providing comprehensive information and necessary explanations could increase user trust [42]. However, directly displaying the detailed trust information (e.g., how these values are generated and who provides this information) could influence usage experience due to the limited screen size of mobile devices.

Though application reputation helps users select a proper application for purchase and installation, we still faced an important system design issue:

> Is it helpful for the users if we display the real-time trust information (i.e., trust and/or reputation values) during the application usage or consumption?

The work presented in this article aims to evaluate the impact of visualizing trust information on mobile application usage. We try to explore the following research questions:

1. How important do people consider various mobile applications?
2. How does individual trust information affect mobile application usage?
3. How do the individual trust and public reputation affect mobile application usage?

3.2 Experiment overview

We developed an experiment toolkit and conducted a three-stage user study to investigate the above research questions in both China (CN) and Finland (FI). We adopted 48 mobile applications and recorded their usage videos. The 48 mobile applications were selected from real products or prototypes, which provide a diverse sample of various mobile application scenarios and usage contexts. Examples include mobile enterprise solutions (e.g., corporate email checking), mobile personal business solutions (e.g., mobile payment, wallet, and safe box), mobile entertainment solutions (e.g., mobile TV, mobile video/audio/radio/music, gaming, and camera), mobile life and social networking solutions (e.g., mobile search, location-based services, maps, instant messaging, VoIP applications, travel aids, and mobile diary), mobile education solutions (e.g., e-book reader and multi-language translator), and integrated applications that provide an easy access to various mobile Internet services (e.g., Nokia WidSets and Yahoo!Go).

In the first experiment, we assessed the importance of mobile application scenarios. Using this result, we selected a set of 9 applications based on their importance rates (low, medium, and high) and showed them in the later two experiments. In the second and third experiments with different participants, either the trust or trust/reputation indicator was displayed in one experiment block, while no information about trust was given in the other block. For each application usage scenario (shown as a video), we asked participants to rate their willingness to continue consumption and check trust information. The effects of three variables were thus studied, including the availability of trust information, trust information itself (either a trust indicator or a trust/reputation indicator), and the specific mobile application scenario (with different importance rates). The results achieved in both countries were also compared. Table 1 shows the design of Experiments 2 (E2) and 3 (E3).

Table 1 The design of Experiments 2 and 3

Experiment variables	Block 1	Block 2
E2		
Indicated trust value	Low, medium, high	Low, medium, high
Indicator availability	No	Yes
Application importance	Low, medium, high	Low, medium, high
Region (test sites)	Finland and China	Finland and China
E3		
Indicated (trust value) × (reputation value)	(low, medium, high) × (low, medium, high)	(low, medium, high) × (low, medium, high)
Indicator availability	No	Yes
Application importance	Low, medium, high	Low, medium, high
Region (test sites)	Finland and China	Finland and China

4 Experiments and results

4.1 Experiment 1: Application's importance

The goal of this experiment is to introduce an importance rate (IR) into each candidate mobile application and select a set of applications for the second and third experiments. We define importance as how important a specific task that a mobile application can fulfill is to the participant concerning its usefulness and personal interest. To determine the IR, Experiment 1 assesses the preferred scale of each participant for each candidate application.

4.1.1 Experimental toolkit

The experimental toolkit contains a number of testing slides. Each testing slide is divided into four parts under the application name. As shown in Fig. 1, Part 1 is a brief introduction of the mobile application. Part 2 is the

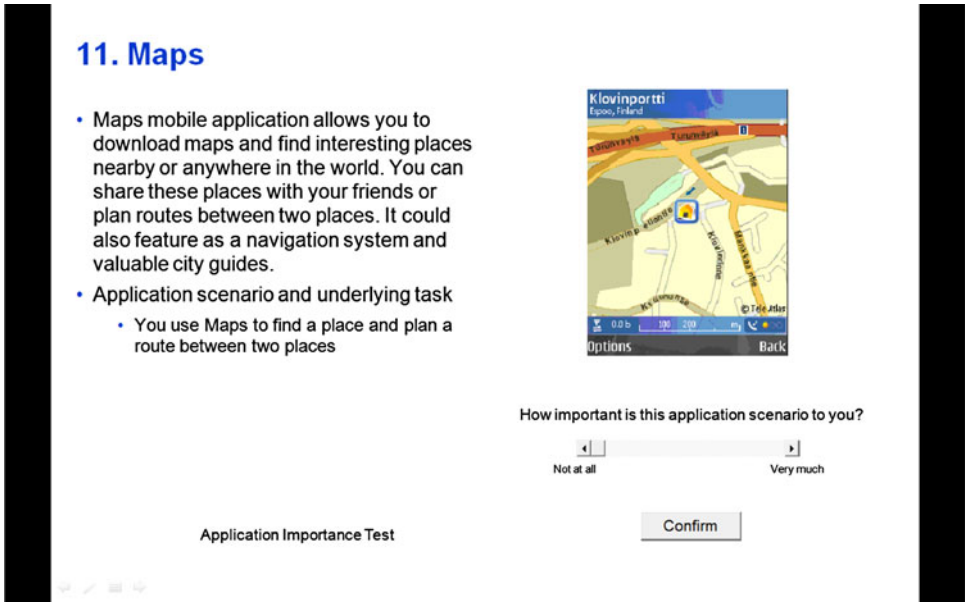

Fig. 1 Example testing slide for Experiment 1

explanation of assumed application scenario and an underlying task. Part 3 is a video recording of the application usage. The videos last from 48 s to 3 min and 17 s. We used a PhoneScreen [44] application developed by the Nokia Research Center (installed at the mobile phone and PC) to show the mobile phone screen on a PC screen through a Bluetooth connection. We used the screen capture tool SnagIt v8.2 [57] (installed on the PC) to record the whole application usage scenario procedure. Part 4 is a feedback area where the participant can use the scroll bars to provide his/her feedback.

The experiment data were automatically recorded during the experiment. These data include the personal information of participants (e.g., name, contact, gender, nationality, profession, and experiences in using mobile applications), the answers, and feedback from questions and interviews.

4.1.2 Participants

In Finland, 26 participants from European countries, mainly from universities, participated in this study. We selected 23 valid samples (39.1 % female) for data processing. This group ranged in age mostly from 19 to 29 years, and 87.0 % majored in science and technology, while others majored in arts (8.7 %) and business (4.3 %). In China, we selected 26 valid samples (61.5 % female) from a total of 31 participants for data processing. The sample was composed of 13 graduates and 13 undergraduates. This group ranged in age from 19 to 29 years, and 7.7 % majored in science and technology, while 57.7 % majored in arts and 34.6 % in business. Table 2 provides information about the participants' experience in mobile application usage.

Table 2 The experience of participants in mobile application usage (Experiment 1)

Experience on mobile applications	Number of participants		Percent (%)	
	Finland	China	Finland	China
Time of phone usage				
Below 0.5 h/day	8	1	34.8	3.8
0.5–1 h/day	9	4	39.2	15.4
1–5 h/day	5	11	21.7	42.3
More than 5 h/day	1	10	4.3	38.5
Total	23	26	100	100
Mobile application usage experience				
Internet accessed applications	18	13	78.3	50
Mobile network accessed applications	22	26	95.7	100
Non-network accessed applications	23	26	100	100

4.1.3 Procedure

At the beginning of each test, we first introduced the basic concepts (e.g., mobile application and IR) with examples. We then briefly described the experiment purpose and procedure, as well as the testing toolkit design. Before the real test, each participant practiced on three example "testing slides" to become familiar with the experiment toolkit.

In this experiment, each participant completed a series of application scenarios to assess his/her opinion on application importance. For each scenario, shown as a text

Table 3 Selected mobile applications (FI and CN)

Application groups	IR low		IR medium		IR high	
	FI	CN	FI	CN	FI	CN
Application names	LifeBlog	LifeBlog	Gizmo	MobiReader	Nokia Maps	Camera
	Video download	TextTV	Yahoo!Go	Yahoo!Go	Gmail	Fring
	Shozu	Web browser	M-realplayer	M-realplayer	Web browser	Music player
IR average	.292	.341	.478	.539	.719	.773
IR stdev	.010	.038	.059	.008	.042	.014

description and video, the participant was asked to answer the question:

- How important is this application scenario to you?

A scroll bar was provided for the participants to indicate IR from "not at all" to "very much." The corresponding values attached to them are 0 and 1, respectively. After answering this question, the participant pressed the "Confirm" button. The test automatically proceeded to the next scenario. After each user test, the display order of the application scenarios was shifted by two. Meanwhile, all scroll bar values were reset to 0. For each participant who fulfilled the entire test, we provided him/her a small gift.

At the end of the test, the participant was further interviewed to choose from "Yes", "No", or "Neutral" for the following two questions:

Q1: Do you think it is helpful to get other people's usage information when you decide whether to do some task via a mobile application?
Q2: Do you think your own past usage information could help your consuming decisions regarding a mobile application?

4.1.4 Results

The IRs of the 48 application scenarios varied between .224 and .777 in Finland, with an average of .487 (stdev = .293), and between .314 and .887 in China, with an average of .553 (stdev = .299). This finding showed that the applications adopted in the experiment covered the continuum of importance well. Notably, the participants' view of the mobile applications' importance obviously varied.

We grouped and selected the applications based on the IR. Table 3 shows that the results in Finland and China were different, implying that the opinions on the importance of mobile applications varied in different regions. Surprisingly, one of the high important applications (i.e., mobile web browser) in Finland was treated as unimportant in China, though its usage experience rate was not low (73.9 % in Finland and 49.2 % in China). Three selected applications (i.e., LifeBlog, Yahoo!Go, and Mobile Realplayer) fell into the same IR groups in two countries.

Table 4 Top 10 used mobile applications

Order	Finland		China	
	Mobile applications	Usage experience percentage (%)	Mobile applications	Usage experience percentage (%)
1	Camera	100	Camera	87.7
2	Game	87.0	Music player	78.5
3	Notes	82.6	Show caller ID	66.9
4	Music player	78.3	Mobile realplayer	62.3
5	Internet search	78.3	Game	60.0
6	Web browser	73.9	Palringo	59.2
7	Gallery	69.6	Radio	55.4
8	Radio	69.6	Foreca	54.6
9	Gmail	65.2	Voice recorder	53.1
10	Mobile realplayer	60.9	Trippo weather broadcast	51.5

We further conducted paired sample t tests to evaluate our grouping. The t and p values of the high and medium importance groups were 25.666 and <.005 in Finland, respectively, and 9.517 and <.001 in China, respectively. The t and p values of the medium and low importance groups were 4.775 and <.05 in Finland, respectively, and 9.678 and <.001 in China, respectively. The t and p values of the high and low importance groups were 14.405 and <.005 in Finland, respectively, and 11.16 and <.001 in China, respectively. The results showed that our groupings in both countries were valid.

4.1.4.1 Top 10 used mobile applications The average usage experience percentage of the applied 48 mobile applications was 27.8 % in Finland and 38.0 % in China. This explains that most participants had not used the tested applications in both countries. Table 4 shows that the top used applications were mostly default applications freely

installed by the mobile phone manufacturers (e.g., Camera, Music Player, Notes, mobile Real Player, Radio, Voice Recorder, and Photo Gallery). Mobile internet services (e.g., mobile internet search, web browsing, and mobile email) were becoming popular in Finland. Mobile multimedia applications were widely consumed in both countries. However, the high importance of a mobile application generally links to a high usage experience percentage, but we found an exception in China in web browsers (with medium usage experience but a low IR) and Fring (with low usage experience but a high IR). This result implies that the Chinese participants (especially Chinese university students) considered cheap or free internet telephone (VoIP) applications more important than did European participants. This finding could be caused by the economic status of participants in different regions when the experiment was conducted.

4.1.4.2 Usage information's assistance The feedback of Q1 and Q2 showed that most participants in Finland (87.0 %) and China (88.5 %) thought it helpful to obtain usage information from other users when they decide whether to do some task via a mobile application. The participants also thought their own historical usage information could help their consuming decisions during mobile application usage in Finland (78.3 %) and China (100 %). This result proved the usefulness of the system that provides trust information to users based on usage statistics, described in Sect. 3.1.

4.2 Experiment 2: Impact of a trust indicator on mobile application usage

The goal of this experiment is to study the impact of a trust indicator (TI) on mobile application usage. We try to investigate if visualizing the individual trust value could assist in mobile application usage.

4.2.1 Design

We applied a design with three independent variables: application scenario (with an IR), TI, and indication availability, that is, whether the indicator is displayed. We also tried to investigate regional influence in our study.

This part of experiment was conducted in two blocks. In Block 1, no information about trust was given, while the TI was displayed in Block 2. The independent variable application scenario was randomized in both blocks. We used the 9 applications previously chosen in Experiment 1. The scenarios in Blocks 1 and 2 were different regarding the same application. Inside Block 2, however, we applied the same scenarios for each application with different trust values indicated. The selected 9 scenario sequences were thus repeated at 3 different individual trust values (Low—0.15, Medium—0.5, and High—0.9). This design resulted in 9 × 3 trials in Block 2. The application scenario order was counterbalanced across participants.

4.2.2 Experimental toolkit

Each testing slide in Experiment 2 contains the test for one mobile application scenario and its structure is the same as in Experiment 1. The application usage videos last from 34 s to 2 min and 1 s. Figure 2 provides an example testing slide.

4.2.3 Participants

In Finland, most participants were university students. We selected 15 samples of native Europeans (26.7 % female)

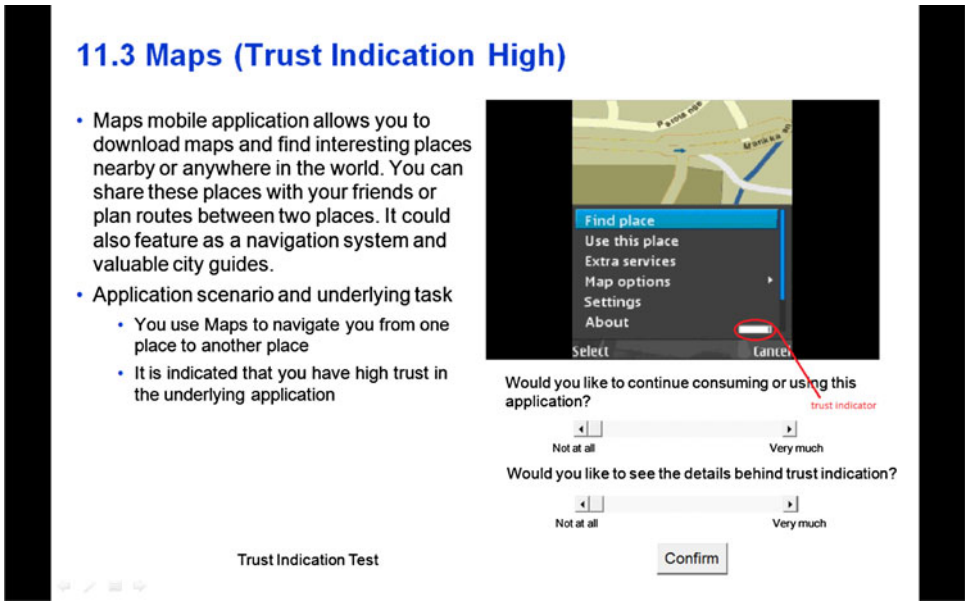

Fig. 2 Example testing slide for Experiment 2

Table 5 The participants' mobile application usage experience (Experiment 2)

The experience on mobile applications	Number of participants		Percent (%)	
	Finland	China	Finland	China
Time of phone usage				
Below 0.5 h/day	5	1	33.3	6.7
0.5–1 h/day	6	8	40	53.3
1–5 h/day	4	1	26.7	6.7
More than 5 h/day	0	5	0	33.3
Total	15	15	100	100
Mobile application usage experience				
Internet accessed applications	13	4	86.7	26.7
Mobile network accessed applications	15	15	100	100
Non-network accessed applications	15	14	100	93.3

from a total of 31 participants for data processing. This group ranged in age from 18 to 30 years and mainly came from science and technology departments (73.3 %). In China, all participants were Chinese undergraduates or graduates, and 30 participants took part in this study. We randomly selected 15 (40 % female) valid samples for data processing. This group ranged in age from 19 to 29 years, and majored in arts (60 %), science and technology (20 %), and business (20 %). Table 5 provides information about the participants' mobile application usage experience.

4.2.4 Procedure

In Experiment 2, each participant completed a series of scenarios without the trust indicator in Block 1 and with the trust indicator in Block 2. We assessed his/her willingness for continuous consumption and the willingness to see the trust value of the application (Block 1) or the detailed trust information (Block 2). For each scenario, the participant was asked to answer the following questions:

- Would you like to continue consuming or using this application? (In Blocks 1 and 2)
- Would you like to see the trust value of this application? (In Block 1)
- Would you like to see the details behind the trust indicator? (In Block 2)

After each user test, the test order of the application scenarios in Blocks 1 and 2 was shifted by 1 and 3, respectively, in a counterclockwise direction. Meanwhile, all scroll bar values were reset to 0. Each participant in both countries was rewarded a gift after the testing.

At the end of the test, each participant was further interviewed to answer several questions:

Q3: Would you like to share your personal usage information: e.g., usage times, usage time, and frequency?
Q4: Do you think your usage information is private?
Q5: What details would you like to see behind the trust indication?
Q6: How do you prefer to access the details?

4.2.5 Results

4.2.5.1 Usage willingness with and without a trust indicator An analysis of variance (ANOVA) was performed to test the impact of the trust indicator on mobile application usage, with the IR (high, medium, and low) and TI value (high, medium, and low) as within-subject factors, reported in Table 6. We found significant main effects of the IR and the trust value (TV), indicating that the willingness of continuously using a mobile application increased with the IR from low to high and the TV from low to high, shown in Fig. 3 with standard errors. The interaction between IR and TV was not significant in both countries. This interaction indicated that the effect of TV did not differ over application scenarios with different IRs.

We conducted paired sample t tests to examine the impact of the trust indicator on mobile application usage. Table 7 compares the results in two countries. We found that usage willingness was higher in Finland, but somehow a bit lower in China (for the IR high and medium applications), with the trust value indicated as high (TV_H) than that without any trust indicator (NO_TI). This usage willingness difference reached a marginal significance level in Finland. Usage willingness was lower with medium and low trust value indicators (TV_M and TV_L) than that without any trust indicator. The results showed that the trust indicator had a significant impact on usage willingness. The willingness also varied according to the displayed trust value. The results implied that the existence of a TI might have a positive impact in Finland (in case of a

Table 6 Experiment 2 ANOVA results on usage willingness

Factors	Effects in Finland (FI)	Effects in China (CN)
IR	F (2, 28) = 11.419, $p < .000$, $\eta = .67$	F (2, 28) = 3.274, $p = .069$, $\eta = .436$ (marginally significant)
TV	F (2, 28) = 17.569, $p < .000$, $\eta = .75$	F (2, 28) = 13.466, $p < .005$, $\eta = .7$
IR × TV	F (4, 56) = 1.943, $p = .158$, $\eta = .35$	F (4, 56) = .521, $p = .655$, $\eta = .19$

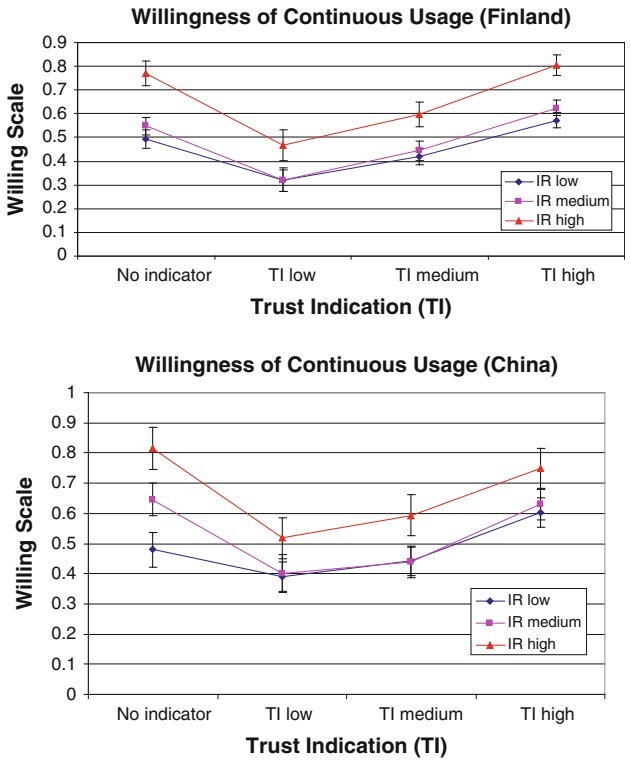

Fig. 3 Usage willingness with and without a trust indicator (Finland and China)

Table 7 Paired samples *t* test on usage willingness with and without a trust indicator

Pairs	Finland		China	
	t	*p*	*t*	*p*
NO_TI–TV_L	7.416	<.000	3.374	=.005
NO_TI–TV_M	3.703	<.006	3.510	<.005
NO_TI–TV_H	−1.673	=.133	−.511	=.617

high indicated trust value) but a negative impact on usage willingness in China, even though a high trust value was indicated.

4.2.5.2 Willingness to check trust information with and without a trust indicator We conducted a two-way (IR × TV) repeated measure ANOVA to test the impact of the TI on a user's willingness to check detailed information behind trust indication. We found a very significant impact of TI [$F(2, 28) = 8.016, p < .01, \eta = .60$] only in Finland. This indicated that the willingness to check the detailed trust information behind trust indicator did not vary over the IR and indicated TV in China, but over the indicated TV in Finland, shown in Fig. 4 (with standard errors).

The paired samples *t* tests also showed that the TI affected check willingness according to its displayed values. The effects were different in two countries. As shown

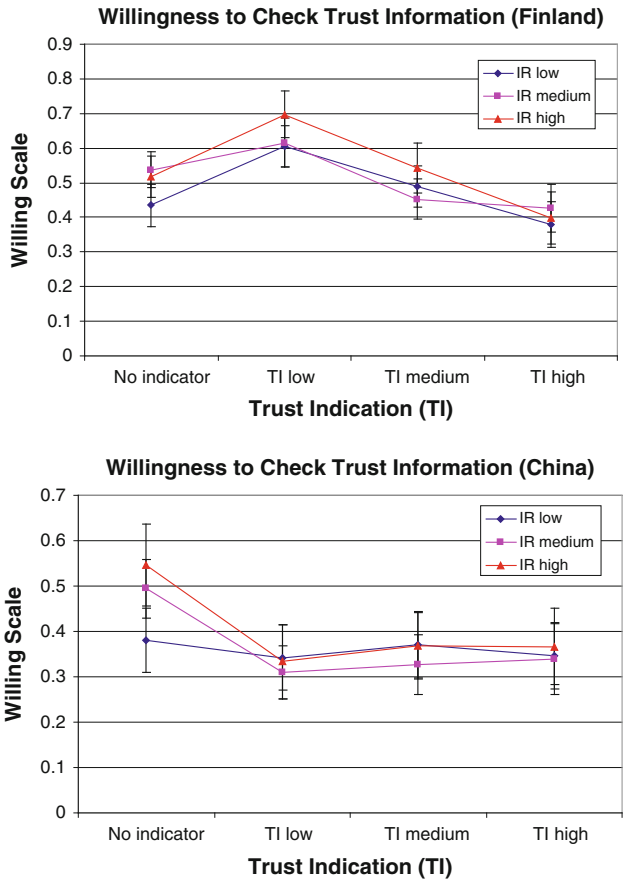

Fig. 4 Willingness to check trust information with and without a trust indicator (Finland and China)

Table 8 Paired samples *t* test on trust information check willingness with and without a trust indicator

Pairs	Finland		China	
	t	*p*	*t*	*p*
NO_TI–TV_L	−4.976	<.001	3.525	<.005
NO_TI–TV_M	.136	.895	3.263	<.01
NO_TI–TV_H	3.363	<.01	2.353	<.05

in Table 8, the check willingness in both countries was lower with a high trust value indicator than that without TI. The check willingness is similar in Finland but lower in China with a medium trust value indicator to/than that without TI. The check willingness is higher in Finland but lower in China with a low trust value indicator than that without TI.

4.2.6 Discussion

We found similar results in both countries regarding usage willingness, but we obtained different results about the

willingness to check trust information. The check willingness was lower when there was a TI than that without TI in China. In Finland, however, the check willingness was higher when there was low trust indication than that without TI. This implies that the Chinese participants relied on (or believed in) the TI more than the European participants. The European participants were more curious about the trust information details if a low trust value was shown. The trust value significantly influenced their check willingness. For most tested mobile applications, the average willingness to know the trust value was approximately 0.5 in both countries, implying that it is significant to provide a feature to show trust information during mobile application usage.

According to the data collected in Experiment 2 (Table 5), European participants (86.7 %) had more experience in using internet-access applications (e.g., Email service and web browser) than Chinese participants (26.7 %). The mobile phone usage time of the Chinese participants was much longer than European ones. The results indicated that mobile internet applications were still not popular in China, but the mobile phone played an important role in the life of Chinese university students.

Table 9 tabulates the interview results from Experiment 2. It implies that most participants would like to share usage information in both countries, but the percentage was higher in Finland than in China. In China, more participants did not want to share personal usage information. In both countries, most participants thought that usage information was private; indeed, a higher percentage was reached in China than Finland, where more participants held neutral opinion. In both countries, about half of the participants thought a menu was their preferred way to obtain trust information details. In Finland, over half of the participants liked using a touch screen, but no participants preferred it in China. In China, some participants preferred shortcut key access.

Table 9 Participants' feedback about usage information and trust indication (E2)

Questions	Answer	Number of participants		Percentage (%)	
		Finland	China	Finland	China
Would you like to share your personal usage information?	Yes	12	10	80	66.7
	No	1	4	6.7	26.6
	Neutral	2	1	13.3	6.7
	Total	15	15	100	100
Do you think your usage information is private?	Yes	11	14	73.3	93.3
	No	0	0	0	0
	Neutral	4	1	26.7	6.7
	Total	15	15	1	100
How do you prefer to obtain the details of trust information? (multi-choice)	Menu	7	9	46.7	60
	Shortcut keys	0	4	0	26.7
	Touch screen	9	0	60	0
	Others	2	2	13.3	13.3
	Total	18	15	120	100

4.3 Experiment 3: Impact of a trust/reputation indicator on mobile application usage

Based on the interview results from Experiment 1, public trust and usage information from other people could be helpful for mobile application consumption. Experiment 2 only investigated the impact of visualizing individual trust information on mobile application usage. Experiment 3 further explored the impact of visualizing both individual trust and public trust (reputation) on mobile application usage. We investigated the mutual influence of visualizing these two pieces of information and studied whether the trust/reputation indicator (TRI) could assist mobile application usage.

4.3.1 Design

This experimental design is similar to Experiment 2. Three independent variables were applied, including the application scenario (with an IR), the TRI, and indication availability. As in Experiment 2, this experiment was conducted in two blocks. In Block 1, no information about trust/reputation was given, while the TRI was displayed in Block 2. The selected 9 application scenario sequences were repeated at 9 different trust/reputation values (Low—0.15, Medium—0.5, and High—0.9 × Low—0.15, Medium—0.5, and High—0.9). This design resulted in 9 × 9 trials in Block 2.

4.3.2 Experimental toolkit, participants, and procedure

The same toolkit was used. In the test, the letters T and R were marked beside the rectangular and trapezoidal bars to help the participants easily identify the trust and reputation values. Figure 5 shows an example testing slide.

In Finland, most participants were university students. We selected 15 (26.7 % female) valid samples provided by native Europeans from 26 participants for data processing. This group ranged in age from 19 to 29 years and majored in science and technology (53.3 %), business and law (26.7 %), and arts (20 %). In China, all participants were Chinese university students, and 31 participants took part in this study. We randomly selected 15 (66.7 % female) valid samples for data processing and comparison with the data obtained in Finland. This group ranged in age from 19

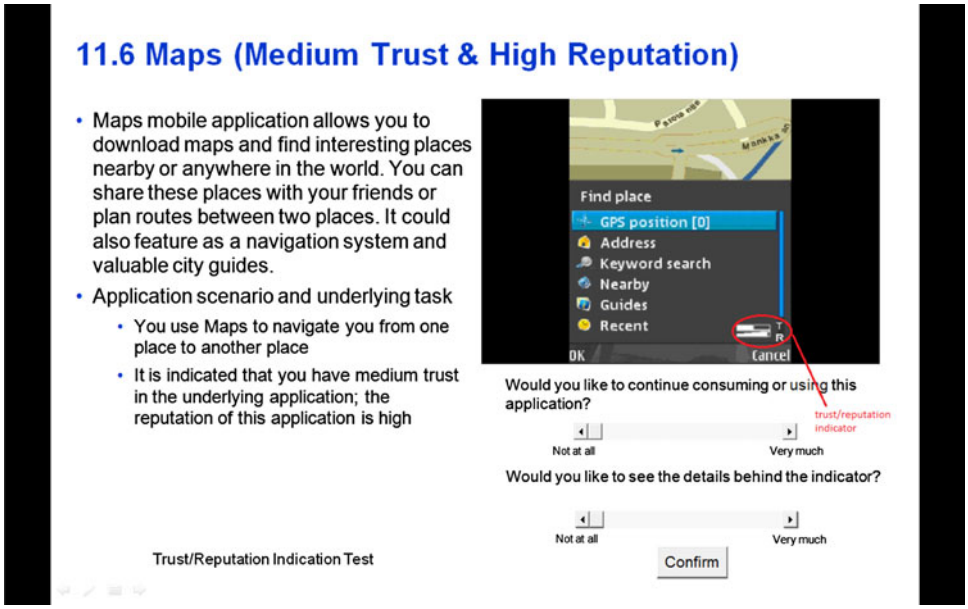

Fig. 5 Example testing slide for Experiment 3

Table 10 The participants' mobile application usage experience (Experiment 3)

The experience on mobile applications	Number of participants		Percent (%)	
	Finland	China	Finland	China
Time of phone usage				
Below 0.5 h/day	2	1	13.3	6.7
0.5–1 h/day	7	3	46.7	20
1–5 h/day	6	9	40	60
More than 5 h/day	0	2	0	13.3
Total	15	15	100	100
Mobile application usage experience				
Internet accessed applications	13	8	86.7	53.3
Mobile network accessed applications	15	15	100	100
Non-network accessed applications	15	12	100	80

to 29 years and majored in arts (60 %), science and technology (13.3 %), and business (26.7 %). Table 10 provides information about the participants' mobile application usage experience.

The procedure of this experiment was the same as that of Experiment 2. For each scenario, the participant was asked to answer similar questions to E2 as below.

- Would you like to continue consuming or using this application? (Blocks 1 and 2)
- Would you like to see the trust/reputation values of this application? (Block 1)
- Would you like to see the details behind the trust/reputation indicator? (Block 2)

After each user test, the test order of the application scenarios was shifted by 1 and 9 in Blocks 1 and 2 in a counterclockwise direction, respectively. Meanwhile, all scroll bar values were reset to 0. Each participant in both countries was given a gift after the testing.

4.3.3 Results

4.3.3.1 Usage willingness with and without a trust/reputation indicator The usage willingness scale was subjected to ANOVA with three within-subject factors: IR (high, medium, and low), indicated trust value (TV) (high, medium, and low), and indicated reputation value (RV) (high, medium, and low), reported in Table 11. We found significant main effects of IR, TV, and RV, indicating that the willingness of continuous usage increased with the IR from low to high, the indicated trust value from low to high, and the indicated reputation value from low to high in

Table 11 Experiment 3 ANOVA results on usage willingness

Factors	Effects in Finland (FI)	Effects in China (CN)
IR	F (2, 28) = 14.899, $p < .001$, $\eta = .72$	F (2, 28) = 1.043, $p = .354$, $\eta = .26$
TV	F (2, 28) = 36.439, $p < .001$, $\eta = .85$	F (2, 28) = 35.926, $p < .001$, $\eta = .85$
RV	F (2, 28) = 27.789, $p < .001$, $\eta = .81$	F (2, 28) = 15.807, $p < .001$, $\eta = .73$
IR × TV	F (4, 56) = .939, $p = .422$, $\eta = .25$	F (4, 56) = 2.777, $p < .05$, $\eta = .41$
TV × RV	F (4, 56) = 6.409, $p < .005$, $\eta = .56$	F (4, 56) = 8.780, $p = .001$, $\eta = .60$
IR × TV × RV	F (8, 112) = .436, $p = .771$, $\eta = .17$	F (8, 112) = 2.039, $p < .05$, $\eta = .36$

both countries, shown in Fig. 6 with standard errors. There was significant interaction between IR and TV in China but not in Finland. However, there was significant interaction between TV and RV in both countries. The interaction effect among IR, TV, and RV was significant in China but not in Finland. This interaction indicated that the effect of trust and/or reputation values did not differ over application scenarios with different IRs in Finland, but this situation was different in China. The effect of TV differed from RV significantly in both countries, and vice versa. No other interactions reached significant levels in either country.

The paired samples t test also indicated that the TRI had a significant impact on usage willingness according to its displayed values, shown in Table 12. We found that the willingness of usage was higher with high trust/high reputation indicator (TRI_HH) than that without any indicator (UW_NOTRI). Usage willingness is similar with high trust/medium reputation (TRI_HM) or medium trust/high reputation (TRI_MH) indicators to that without TRI in Finland [t (14) = .105, p = .919; t (14) = .542, p = .603]. This similarity only occurs in TRI_HM [t (14) = 1.372, p = .192] in China. Usage willingness is significantly lower than other values shown by TRI than that without the TRI (Table 12).

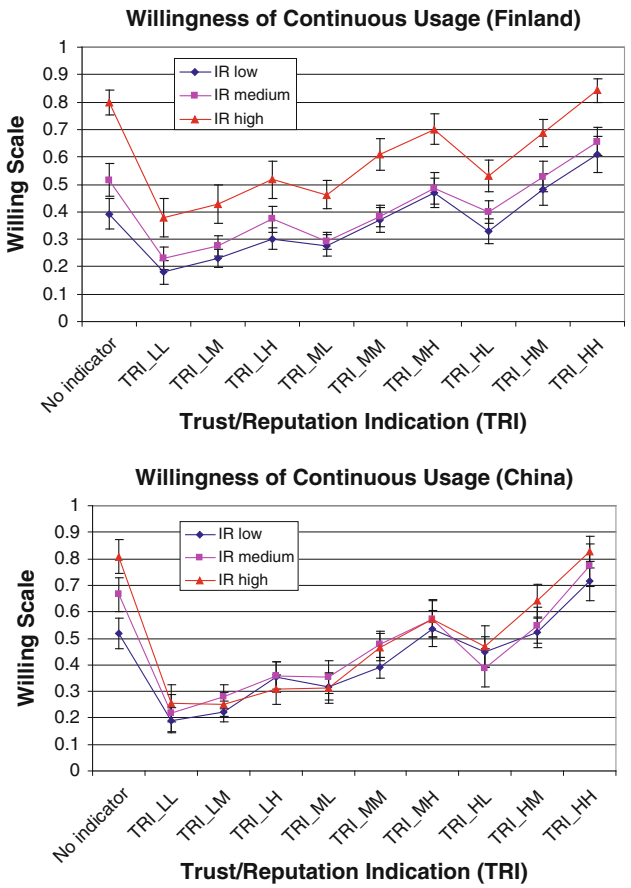

Fig. 6 Usage willingness with and without a trust/reputation indicator (Finland and China)

Table 12 Paired samples t test on usage willingness with and without a trust/reputation indicator

Pairs	Finland		China	
	t	p	t	p
NO_TRI–TRI_LL	8.506	.000	5.903	.000
NO_TRI–TRI_LM	7.018	.000	10.118	.000
NO_TRI–TRI_LH	5.196	.001	7.106	.000
NO_TRI–TRI_ML	6.053	.000	4.850	.000
NO_TRI–TRI_MM	3.461	.009	4.027	.001
NO_TRI–TRI_MH	.542	.603	1.906	.077
NO_TRI–TRI_HL	3.708	.006	2.854	.013
NO_TRI–TRI_HM	.105	.919	1.372	.192
NO_TRI–TRI_HH	−3.782	.005	−1.639	.123

4.3.3.2 Willingness to check trust information with and without a trust/reputation indicator We conducted a three-way (IR × TV × RV) repeated measure ANOVA to test the impact of TRI on user willingness to check detailed trust information behind the indicator. Figure 7 (with standard errors displayed) shows that a significant main effect of TV [F (2, 28) = 7.466, $p < .05$, η = .59] and RV [F (2, 28) = 5.766, $p < .05$, η = .54] was found in China; TV and RV influenced the check willingness independently. No other main effects and interactions reached statistical significance in China, but there was a significant interaction between TV and RV in Finland [F (4, 56) = 5.062, $p < .05$, η = .51], implying that the effect of trust value on check willingness is further influenced by the reputation value in Finland and vice versa.

Table 13 shows that the paired samples t test implied that as the difference between the trust and reputation values becomes sharper, the willingness to check the detailed trust/reputation information in Finland increases. However, check willingness is generally lower with the TRI than without any indicator in China. The result indicated that the TRI had a positive impact on check willingness according to its displayed values.

4.3.4 Discussion

We found similar results in both countries regarding usage willingness, which increased with the application IR, TV, and RV. The result also implied that there were reciprocal effects between the trust value and the reputation value on mobile application usage willingness.

We obtained different results about the willingness to check trust information in the two countries. The check

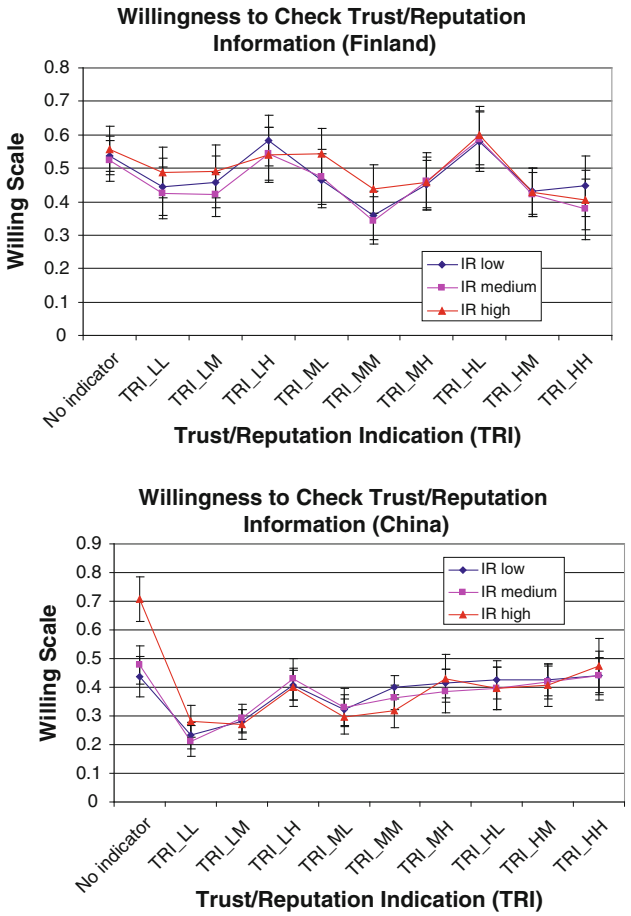

Fig. 7 Willingness to check trust information with and without a trust/reputation indicator (Finland and China)

Table 13 Paired samples *t* test on check willingness with and without a trust/reputation indicator

Pairs	Finland		China	
	t	*p*	*t*	*p*
CW_NOTRI–TRI_LL	2.943	.019	4.447	.001
CW_NOTRI–TRI_LM	3.840	.005	4.999	.000
CW_NOTRI–TRI_LH	−.710	.498	1.957	.071
CW_NOTRI–TRI_ML	1.784	.112	3.758	.002
CW_NOTRI–TRI_MM	7.428	.000	3.525	.003
CW_NOTRI–TRI_MH	3.908	.004	2.225	.043
CW_NOTRI–TRI_HL	−1.728	.122	2.130	.051
CW_NOTRI–TRI_HM	5.654	.000	2.827	.031
CW_NOTRI–TRI_HH	4.983	.001	1.390	.186

willingness was lower when there was a TRI than that without any indicator in China, but the check willingness was higher in Finland than that without any trust/reputation indication when the indicated trust and reputation values were different. This result implied that the Chinese participants relied on (or believed in) the TRI more than the European participants. The European participants were more curious about the trust information details if the displayed trust value sharply differed from the reputation value. The trust and reputation values interactions with each other significantly influenced the check willingness. In addition, the average willingness to know the trust/reputation value was above 0.5 for most tested mobile applications in both countries, implying that it is significant to provide a feature to show trust information during mobile application usage.

Table 14 Participants' feedback about usage information and trust indication (Experiment 3)

Questions	Answer	Number of participants		Percent (%)	
		Finland	China	Finland	China
Would you like to share your personal usage information?	Yes	9	8	60	53.3
	No	5	6	33.3	40
	Neutral	1	1	6.7	6.7
	Total	15	15	100	100
Do you think your usage information is private?	Yes	11	13	73.3	86.6
	No	3	1	20	6.7
	Neutral	1	1	6.7	6.7
	Total	15	15	100	100
How do you prefer to obtain the details of trust information? (multi-choice)	Menu	8	9	53.3	60
	Shortcut keys	3	4	20	26.6
	Touch screen	3	1	20	6.7
	Others	2	1	13.3	6.7
	Total	16	15	106.6	100

Table 10 shows that we obtained results similar to those from Experiment 2. The phone usage time in China was generally much longer than that in Finland. However, fewer Chinese participants experienced internet-access mobile applications than European participants.

Table 14 tabulates the interview results of Experiment 3. In both countries, over half of the participants would like to share usage information, but the percentage was slightly higher in Finland than in China. In China, more participants did not want to share personal usage information. In both countries, most people thought the usage information was private, but the percentage was higher in China than in Finland. In both countries, about half of the participants preferred getting the trust information details via a menu. More participants liked using touch screen in Finland than in China. In both countries, some participants preferred shortcut key access.

5 General discussion and conclusion

5.1 Impact of trust information indication

Trust can greatly overcome uncertainty and thus influences usage confidence. In this article, we proposed displaying trust/reputation information to assist mobile application usage. The effectiveness of the visualization was shown from a three-stage user study conducted in both Finland and China.

We contribute a user study design to investigate opinions on mobile application usage. Using this design, we first identified the importance of various mobile applications in two countries with different cultures and technology backgrounds. This, as we know, has not been studied in the literature. We then selected a number of candidate applications with different IRs to examine how users react to the display of their own individual trust values and that of both individual and public trust (reputation). We found that visualizing the trust and trust/reputation values makes a significant difference, as users tend to change their usage behaviors and decisions. The experimental results indicated that both the trust and trust/reputation indicators have significant impacts on usage willingness according to their displayed values. These two indicators also have valuable impacts on the willingness to check detailed trust information, though the results in two countries differed. We found different usage willingness and trust information check patterns in two countries. Our results suggest the importance of visualizing trust information on mobile application usage and its potential to improve mobile application usability. Our experiments investigated the interaction effects among application importance, trust value, and/or reputation value on application usage and trust information check.

5.2 Other impact factors

Except for providing useful trust information, many other factors can influence mobile application usage. We found that the participants' opinions were sharply different, even in the same situations. Personality was an important factor that might affect usage decision and behavior. Different personalities attributed different importance levels to each accepted trust cue (including branding, third-party security seals, clearly stated policies, vendor information, and professional user interface design). Extroversion and openness to experience led to a higher disposition to trust, but neuroticism and conscientiousness lead to a lower disposition to trust [33, 59].

We also noticed that the results were different in Finland and China, especially on the willingness to check trust information. Because the ages and occupations of selected participants were similar in both countries, potential reasons for these differences include culture deviation, past usage experiences, the technical background of the participants, and regional technology development status.

Cultural difference influenced trust in an on-line environment [25]. The same influence could also apply to mobile application scenarios. More generally, social trust levels varied substantially among countries [24]. The culture-dependent nature of trust suggests that trust in HCI may need to be verified when it is extrapolated from one culture to another. Zuboff [71] found that the culture associated with people who had been exposed to computers led to trust and acceptance of automation. There was significant deviation between Chinese and European participants, reflecting the difference of eastern and western cultures. Our experimental results showed little difference in usage willingness and obvious difference in check willingness. One explanation could be that the Chinese participants more easily trusted the information provided by a system and did not want to figure out the real reasons behind it, though they could become caustic if some information was provided. Conversely, the European participants were more curious about the reasons behind the difference between individual trust and reputation. The European participants wanted to explore why the trust value was low and why there was a sharp difference between these two pieces of information. These participants generally reacted more positively to the indicated trust information compared to the Chinese participants. The importance of mobile applications influenced their behaviors more than those of the Chinese participants.

Deviation of past usage experience could be another reason behind the different results. Riley [50] found that pilots who were accustomed to using automation trusted and relied on automation more than students who were not familiar with it. These results showed that past experiences influenced trust in a digital system. Though mobile phone usage time was generally longer in China than that in Finland, the applications experienced by and familiar to the Chinese participants were different than those in Finland. For unfamiliar applications, participants could hesitate to make a usage decision, even if additional trust information was provided. The participants could, however, be curious about consuming useful and important applications, even having no previous experience. This is more obvious in China than Finland, shown by a higher average willingness to use applications in the situation without any indicator in China than in Finland.

Apart from the above, the technical background of participants could be another factor that may impact application usage. In Finland, most participants had a background in information and computer science, while most participants majored in arts and business in China.

The knowledge background could influence usage behaviors even in the same situation. Conversely, the technology development situations were obviously different in the two countries. The above factors could cause different past usage experiences for the participants and their familiarity with related technologies. However, these two factors are important factors influencing trust and use. The technical background and regional technology development status could thus be other potential reasons that might cause different experimental results in two countries.

5.3 Implications

We found that usage willingness without any trust information indication was a bit lower than that with high trust or high trust/high reputation indication. This result implied that the blind or initial trust of the participants was generally high. This finding is the same as in previous research [38, 39]. We suggest that the initial individual trust value, indicated by the trust management system, should be set correspondingly high when a user has no experience with an application, especially when trying to encourage usage. This value can later be evolved (increased or decreased) according to accumulated usage experience and behaviors [68, 69]. The results also implied that the TRI was more instructive for mobile application usage than the TI, though the TI could also independently impact usage behavior and decisions; the Chinese participants somehow showed suspicion about the TI.

Except for the experimental tests, we also interviewed all participants in both China and Finland. All Experiment 1 participants (100 %) in China thought their past usage history information could help their consuming decisions on mobile applications, while 78.3 % of the participants in Finland held the same opinion, though 8.7 % had a different opinion and 13 % were neutral. In Finland, 87 % of the participants thought other usage information is helpful when making a usage decision, 4.3 % did not agree on it, and 8.7 % were neutral. In China, 88.5 % of the participants provided a positive answer; no participants gave a negative answer, and 11.5 % were neutral. The above data additionally indicated the assistance of personal and public usage information on mobile application consumption. This result also indicates the foundation of trust and reputation generation based on trust behavior statistics [68, 69]. The result further implied that it was useful to provide usage statistics when the user would like to check the detailed trust information. This information explains the credibility of trust and reputation, thus enhancing user confidence on the trust management system of mobile applications.

From interviews with 60 Chinese and European participants in Experiments 2 and 3, we found that most participants would like to share usage information. The percentage was higher in Finland (70 %) than China (60 %). In China, more people did not want to share personal usage information (33.3 % in China and 20 % in Finland). In both countries, most people thought that usage information was private. The percentage was much higher in China (90 %) than Finland (73.3 %), where some participants thought that usage information was not private (10 %) and held a neutral opinion (16.7 %). This result actually explained the main reason that we conducted the second experiment about the trust indicator, should the reputation not be easily achieved or credible due to privacy concerns in practice. In both countries, about half of the participants preferred using the menu to obtain trust information details (50 % in Finland and 60 % in China). In Finland, many more participants (40 %) preferred touch screen access (touching the indicator icon) than in China (3.3 %). In both countries, some participants preferred shortcut key access; the percentage for this preference was slightly higher in China (26.7 %) than in Finland (10 %).

The participants held positive opinions on the trust and trust/reputation indicators. Many participants commented that the indicator did not bother them at all but that it was helpful and useful and provided good information. These participants sometimes preferred to see the indicator. Riegelsberger et al. [49] found that signaling trust-warranting intrinsic and contextual properties is particularly important when no previous experience with a trustee is available, especially in first- or one-time interactions. We received similar comments from the participants in our experiments. Most participants thought the indicators shown in the test were well designed. Some participants preferred personalized displays to control when and how to visualize the indicator. Some participants suggested displaying a transparent indicator to improve usability. Based on the above findings, we suggest providing a mechanism in each mobile application that can customize the trust information visualization in the indicator schemes, indicated times, non-indication period, screen position of the indicator, and visualization duration. We believe that this mechanism can flexibly satisfy various users with different personalities and culture backgrounds.

The experimental results also provided a number of guidelines for designing and developing a trust management system for mobile applications with a trust/reputation visualization mechanism.

- Friendly UI design of the trust and trust/reputation indicators is recommended. The participants provided many valuable suggestions on detailed trust information access and display and commented on what they expected to see (i.e., information providers' certificates, reputation credibility, the reason that caused the

difference between the trust and reputation values, how these two values were generated, the most popular features of the application, the option to comment and rate, trust history, the safety index of trust information sharing, application IR, and application error statistics). This feedback provided guidelines for designing the data structure of the detailed trust information. Based on the results and findings, we suggest using three-layer trust information indication. The first layer is the trust or trust/reputation indicator, which is displayed when the user is using the application. The second layer provides detailed trust information behind the indicator, which can be accessed through the option menu of the application or by touching the indicator on the screen. More detailed information can be further accessed through hyperlinks that provide additional explanations.

- People welcome a system that provides the trust/reputation information of mobile applications retrieved from personal and public usage information. The system design should pay special attention to the concerns of normal users and their privacy and support the flexibility to control usage information sharing. Because many participants only accepted anonymous usage information sharing, anonymity support is a necessity. In our experiments, we found a number of expected technologies that should be adopted in such a trust management system, including privacy enhancement technology, such as an anonymous identity for usage information sharing, secure storage to ensure the confidentiality and integrity of the local usage statistical data for individual trust generation, a secure channel to send the usage information or individual trust value to a reputation service provider. Most importantly, it is crucial that users understand the privacy protection solution provided by the system. The trust and trust/reputation indicators are subject to mimicry [49]. We should certify the trustworthiness of the trust and trust/reputation indicators in practice.
- A suitable business model should be adopted to encourage usage information sharing. Based on the interviews, we found that a trustworthy brand greatly benefited a reputable company issuing such a service by providing trust information to mobile application users. Meanwhile, profit campaigns could encourage individual trust information sharing by offering benefits based on sharing credits accumulated by the users.

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