An Empirical Investigation of Smart Product Adoption

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ABSTRACT

The advance of information technologies and the Internet have been enabling the transformation of physical products into smart products by embedding information technologies into the products and thereby making them intelligent. The movement to the 'Internet of Things' is accelerating connection of the products to the net. While those changes could enhance value propositions of products, they might also cause consumer privacy concerns, which might hinder smart product adoption, because the smartness of the product mainly takes advantage of personal information about the users. This study aims to investigate consumers' intention to adopt smart products. Building on previous studies on smart products and privacy literature, we propose a research model that explains factors influencing consumers' intention to adopt smart products. The proposed research model is empirically tested using data from an online survey of consumers. The overall results validate the proposed research model of smart product adoption. Specifically, perceived personalization is found to positively affect consumers' intention to adopt smart products, whereas information privacy risk decreases the intention. We also find that the attributes of personal information are critical antecedents of consumers' risk-benefit assessment. The sensitivity of information increases information privacy risk while the congruency of information enhances perceived personalization. Based on the results, theoretical and managerial implications are discussed.

Keywords: Smart product adoption, perceived personalization, information privacy concern, personal information, attributes of information.

INTRODUCTION

Information technology has been changing physical products drastically, which is being accelerated by the movement to the 'Internet of Things.' The change in physical products includes two major types of transformation. One is digitization of physical products as can be seen in the transformation of books into e-books. The other is transformation into smart products, where the physical form of a product remains, however the product itself get smart. Smart products are defined as "products with digital representations that enable adaptation to situations and consumers." [18, p. 212]. Smart products, containing information & communication technology, are able to collect, process, and produce information, and interact with users, other products, and environments [25].

Whereas digitization of physical products is usually confined to those products whose core values are the information they contain (i.e., information goods), transformation into smart products can be applicable to almost all physical products, offering firms with new opportunities for product innovation. In this regard, Porter and Heppelmann [23] view the transformation as a third transformation information technology has introduced to competition and strategy.

While the change of a product into a smart one could equip the product with enhanced consumer value, it may also cause consumer privacy concerns because the smartness of the product mainly takes advantage of personal information about the users such as their identities, usage behaviors, and/or usage contexts. Therefore, consumers' privacy concerns are a critical issue for firms to address to capitalize on smart products, and a major potential factor that works in consumers' decision to adopt smart products as well.

The main objective of this study is to investigate consumers' intention to adopt smart products. Building on previous studies on smart products and privacy literature, we propose a research model that explains factors influencing consumers' intention to adopt smart products. Specifically, we posit that consumers' adoption decision is guided by the evaluation of the tradeoff between the benefit and cost related to their use of smart products. We consider personalization and information privacy risk as key benefit and cost factors respectively. Further, we link two attributes of personal information with the two factors and propose that sensitivity of information can affect information privacy risk while congruency of information can influence perceived personalization. The proposed research model is empirically tested using data from an online survey of consumers.

The rest of this paper is organized as follows. Related literature is reviewed and research hypotheses are proposed in the following section. We then describe out research methods for online survey and data gathering. Afterward, we analyze the data and provide the analysis results. Finally, we conclude with a discussion about our findings.

THEORETICAL BACKGROUND AND HYPOTHESES

Smart Products

Porter and Heppelmann [23] suggest that smart products consist of three core elements: physical components, "smart" components, and connectivity components; Smart components enhance the capabilities and value of the physical components, while connectivity components amplify the capabilities and value of the smart components and enables some of them to exist outside the physical product itself. The combination of the components leads to enhanced value proposition. The authors categorize functions and capabilities of smart products into four areas: monitoring, control, optimization, and autonomy, each of which sets the stage for the next level [23].

In a similar vein, Rijsdijk and Hultink [24] refer to smart products' abilities collectively that differentiate them from non-smart products as product smartness. Based on this concept, Rijsdijk and Hultink [24][25] suggest seven dimensions of product smartness; autonomy, adaptability, reactivity, multifunctionality, ability to cooperate, humanlike interaction, and personality. The definition of each dimension is summarized in Table 1.

Table 1: Dimensions of Product Smartness [25]

Dimension	Definition
Autonomy	The extent to which a product is able to operate in an independent and goal-directed way without interference of the user
Adaptability	A product's ability to improve the match between its functioning and its environment
Reactivity	The ability of a product to react to changes in its environment
Multifunctionality	The phenomenon that a single product fulfills multiple functions
Ability to cooperate	The ability to cooperate with other devices to achieve a common goal
Humanlike interaction	The degree to which the product communicates and interacts with the user in a natural, human way
personality	A smart product's ability to show the properties of a credible character

At the heart of the above dimensions is the capability of adaptability, which implies that smart products are able to adapt to users and contexts. For example, independent operation of a smart product without the user's interference (autonomy) or reaction to changes in the environment (reactivity) would not be possible without the product's perception of and adaptation to its operating context. Three core components of adaptability include adaptation to situational contexts, adaptation to actors that interact with products, and adaptation to underlying business constraints [18].

Because adaptation is enabled by perceiving information about user activities and context [18, p.212], an indispensable prerequisite for adaptation is collection and use of information about the user and her usage of the product. As such, Porter and Heppelmann [23] argue that the information is fundamental to value creation and competitive edge in smart products. However, the collection and use of personal information cause consumer concerns for their privacy. Therefore, consumers' privacy concerns are not only a critical issue for firms to address to capitalize on smart products, but also a major potential factor that works in consumers' decision to adopt smart products.

Privacy Calculus and Smart Product Adoption

The privacy calculus framework is a well-established theoretical perspective to explain individuals' decisions regarding personal information disclosure [9]. The perspective conceptualizes the individual's privacy interests as an exchange where individuals provide their personal information in return for certain benefits [28]. As such, consumers' privacy decisions are accompanied by an assessment of the costs (risks) and benefits related to information disclosure [8] [10]. A positive net outcome implies that individuals are more likely to accept the loss of their privacy involving disclosure of personal information as long as the level of risk is acceptable [9]. Based on this logic, it is predicted that benefits related to information disclosure increase the likelihood of personal information disclosure while related risks decrease the likelihood.

Because collection and use of personal information is the fundamental source of enhance value proposition of smart products that differentiate them from non-smart products, refusal to personal information disclosure can be equated with refusal to smart product adoption. Therefore, risks related to information disclosure are expected to decrease consumers' intention to adopt smart products, whereas benefits are expected to positively affect the adoption intention.

In this study, we consider information privacy risk as a critical risk factor in consumers' decision. Information privacy risk is defined as potential loss of control over personal information [11]. Previous empirical studies have verified the negative impact of information privacy risk on willingness to disclose personal information [10] [19] [28] and on product/service adoption decisions [11]. Therefore, we suggest the following hypothesis.

H1: Information privacy risk is negatively related to intention to adopt smart products.

We consider perceived personalization as a critical benefit factor in consumers' privacy (therefore adoption) decision regarding smart products. Personalization refers to "the ability to provide content and services that are tailored to individuals based on knowledge about their preferences and behaviors [1, p. 84]." This definition implies that personalization is about people and personalization is adaptive [26]. Therefore, personalization reflects the smart products' key capability, adaptability. Because adaptability (and personalization) is enabled collection and use of personal information, there should be a tension between benefit of personalization and risk of information disclosure in consumer decisions regarding smart products, which is reflected in the concept of 'personalization-privacy paradox' in the privacy literature [3]. Therefore, perceived personalization, a consumer's perception of a smart product's personalization, is expected to increase adoption intention, leading to the following hypothesis.

H2: Perceived personalization is positively related to intention to adopt smart products.

Information Attributes and Privacy Calculus

We consider two attributes of personal information that is collected in the usage of smart products, information sensitivity and information congruency. The attributes are linked with the privacy calculus as antecedents of the risk and benefit factors.

Following Angst and Agarwal [2] and Li et al. [17], information sensitivity is conceptualized as an attribute of personal information that indicates the level of discomfort an individual perceives when disclosing that specific personal information. Disclosure of personal information implies potential of loss of control over that information [28], and individuals' reactions to privacy threats depend on the type of information requested [19] [22]. Because releasing more sensitive information is more likely to instigate risk belief than releasing less sensitive information, information sensitivity is expected to increase information privacy risk. Thus, we suggest Hypothesis 3. Please note that given that information sensitivity is conceptualized as a perception concerning specific personal information, people may attach different levels of sensitivity to the same information, generating variation across people.

H3: Information sensitivity is positively related to information privacy risk.

Information congruency is conceptualized as the degree to which the information requested appears relevant to the purpose of transactions with the firm [27]. In the context of smart product usage, information congruency can be defined as the degree to which an individual perceives that specific personal information collected appears relevant to the purpose of smart product usage. Because personal information is a critical input to personalization, personalization is a function of the information. For congruent information, a consumer would perceive that she could effectively achieve her purpose of smart product usage and, more specifically, enjoy enhanced value in the form of personalization. Therefore, the congruency of information would have a positive effect on perceived personalization.

H4: Information congruency is positively related to perceived personalization.

Figure 1 shows the research model in this study

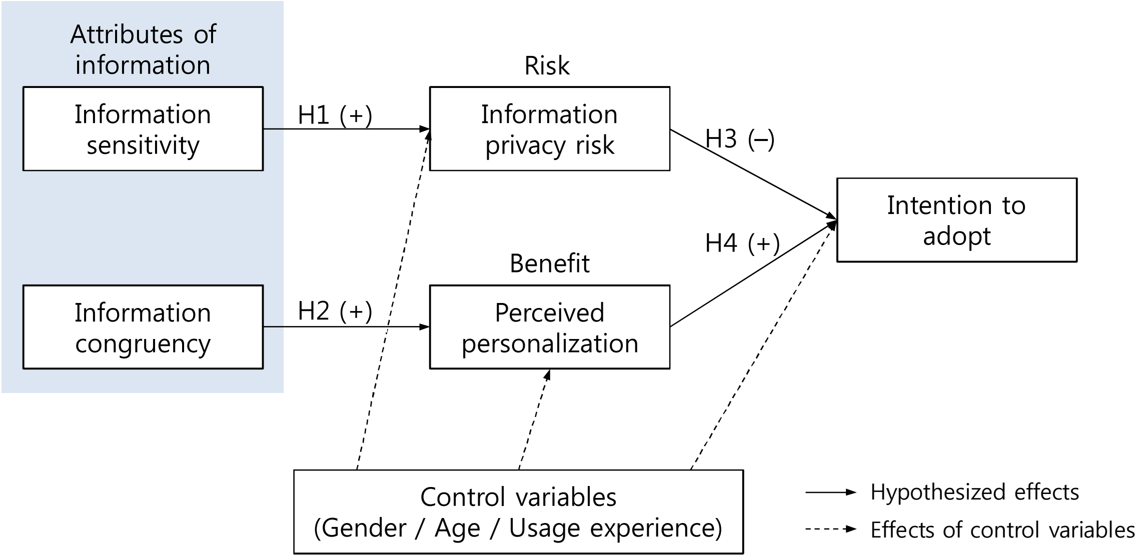


Figure 1: Research Model

RESEARCH METHOD

We conducted an online survey of consumers to test the research model empirically. We chose a real smart product and asked survey participants to respond questions measuring their perceptions about the product. A market research company administrated the survey using its large-scale online panel of consumers.

The smart product we chose was a smart toothbrush by Oral-B. The product was launched in the U.S. and several European countries at the time of the survey. It is an electric toothbrush coupled with a smartphone application through Bluetooth communication. The product offers several smartness features. For example, it provides users with real-time feedback on their brushing by telling exactly which part of the mouth to brush now and displaying the time elapsed on the application screen. Equipped with a pressure sensor, it notifies the user if she toothbrushes too hard. Users can control the operation of the toothbrush by changing the application settings. The application saves the user's brushing history, which can be handed over to dentists to suggest customized dental care.

Electronic toothbrushes are, although the smart toothbrush is not, a popular product category most consumers are acquainted with. Further, a smart toothbrush is a personal appliance each consumer can consider purchasing. Therefore, it was judged appropriate for the empirical context of our study.

Participants and Measurement Items

A total of two-hundred respondents participated in the survey. Among them, seven were screened out owing to insincere responses. We used the remaining data for the analysis (sample size = 193). The demography of the sample shows an equal representation of male (47%) and female (53%) and a well-balanced distribution in age (21% in 20s, 26% in 30s, 31% in 40s, and 22% in 50s or 60s) with an average age of 39.8.

When accessing to the survey site, the respondents were asked to acquaint themselves with the description of the smart toothbrush presented on the screen including its pictures and features. To ensure that the respondents read it carefully, the survey system was set in such a way that they could move to the next page only after they stay on the page during at least thirty seconds. Then, the survey items were presented on the following pages. The items intended to measure the five constructs included in the research model and demographics and control variables. A total of seventeen items were employed as presented in Table 2.

Sensitivity of information was measured with two items based on Hui et al. [13]. Congruency of information was measured using three items adapted from Li et al. [17], where information congruency is measured in the context of membership sign-up for a commercial website. Three indicators measuring information privacy risk were adapted from Xu et al. [28], which examines information privacy and personal information disclosure in the location-based service context. Perceived personalization was measured with three items adopted from Komiak and Benbasat [16] and Sheng et al. [26], which deal with online personalization services. Intention to adopt smart product consists of three items used in Pavlou and Fygenson [21] and Kim et al. [14] to measure adoption intention. All of the items were measured on seven-point Likert scales with 1 being “strongly disagree” and 7 being “strongly agree.”

We measured, as a control variable, electric toothbrush usage experience because there may exist systematic differences in perceived personalization and adoption intention of smart toothbrush between those who have experienced electric toothbrushes and those who have not. We also measured gender and age and used them as control variables.

Table 2: Measurement Items

Construct	Measurement Item	
Information sensitivity (SEN)	SEN1 SEN2	It seems that sensitive personal information is collected during the use of the product. I would feel sensitive about sharing my personal information during the use of the product.
Information congruency (CON)	CON1 CON2 CON3	Personal information gathered seems relevant for effective use of the smart product. Personal information gathered appears to have a bearing upon the purpose of using the product. It seems that personal information necessary for the use of the product is collected and shared appropriately.
Information privacy risk (PRI)	 PRI1 PRI2 PRI3	If I use the product, … providing my personal information during the use of the product would involve many unexpected problems it would be risky to disclose my personal information during the use of the product. there would be high potential for loss in disclosing my personal during the use of the product.
Perceived personalization (PER)	 PER1 PER2 PER3	If I use the product, this product would … understand my needs. know what I want based on my personal information provide me with personalized teeth care functions.
Intention to adopt (INT)	INT1 INT2 INT3	I intend to purchase this product. I am likely to purchase this product. I am willing to use this product for better teeth care.
Gender Age Electric toothbrush usage experience	GEN AGE EXP	What is your gender? What is your age? Have you ever used electric toothbrushes?

ANALYSIS RESULTS

To test the proposed research model, both the measurement model and structural model were analyzed. After examining the measurement model, we provide the results of the hypothesis tests based on the estimation of the structural model.

Evaluating the Measurement Model

We performed a confirmatory factor analysis using AMOS to evaluate the measurement model. A maximum likelihood estimation was employed for the analysis. First, the model fit was examined and fit measures indicated an acceptable fit. The relative (or normed) chi-square value (chi-square / degree of freedom) of 2.19 is lower than the threshold of 3.0 recommended by

Kline [15] and the threshold of 5.0 by Byrne [6]. Fit indices (CFI = 0.96, NFI = 0.92, TLI (NNFI) = 0.94) and RMSEA (= 0.08) also satisfies common criteria [5] [12]. Therefore, the results display a satisfactory level of fit between the measurement model and the data.

Next, construct validity and reliability were evaluated. To assess the convergent validity, we examined the factor loadings, composite reliability, and average variance extracted. As shown in Table 3, all of the factor loadings are greater than 0.6, a common criteria suggested by Bagozzi and Yi [4]. The composite reliability scores are greater than 0.79 for all constructs, exceeding a commonly recommended threshold of 0.7 [20]. Finally, the average variance extracted for each construct is greater than 0.65, exceeding the threshold of 0.5 recommended by Chin [7]. Overall, the convergent validity is considered satisfactory.

The discriminant validity was assessed by comparing the square root of the average variance extracted for each construct with the correlation coefficients between the construct and the other constructs. As shown in Table 4, the amount of the variance captured by each construct is greater than the shared variance with the other constructs. Therefore, it is concluded that the measurement items have a sufficient level of discriminant validity.

Finally, the reliability (internal consistency) was evaluated with Chronbach's α. The last column of Table 3 shows that every construct has a Chronbach's α score greater than 0.79, satisfying the threshold of 0.7 recommended by Nunnally and Bernstein [20]. Further, none of the scores exceeds 0.95, suggesting that concern about common method bias can be ignored.

Overall, the results from the above assessments indicate that the fitness of the measurement model and the validity and reliability of the measurement scales are satisfactory.

Table 3: Factor Loadings, Average Variance Extracted, Composite Reliability, and Chronbach's α

Construct and Item	Factor Loading*	Average Variance Extracted	Composite Reliability	Chronbach's α
Information sensitivity SEN1 SEN2	0.789 0.835	0.660	0.795	0.794
Information congruency CON1 CON2 CON3	0.859 0.899 0.658	0.660	0.851	0.844
Information privacy risk PRI1 PRI2 PRI3	0.796 0.832 0.797	0.654	0.850	0.846
Perceived personalization PER1 PER2 PER3	0.904 0.899 0.825	0.769	0.909	0.908
Intention to adopt INT1 INT2 INT3	0.897 0.892 0.889	0.797	0.922	0.921

Note: 1. * $p < 0.001$ for every factor loading

Table 4: Inter-construct Correlation Coefficients

Construct	Information sensitivity	Information congruency	Information privacy risk	Perceived personalization	Intention to adopt
Information sensitivity	0.812				
Information congruency	0.101	0.812			
Information privacy risk	0.804*	0.126	0.877		
Perceived personalization	0.096	0.513*	0.047	0.809	
Intention to adopt	-0.065	0.365*	-0.114	0.473*	0.893

Note: 1. Value on the diagonal is the square root of average variance extracted (AVE).
2. * $p < 0.01$; for the others, $p > 0.05$.

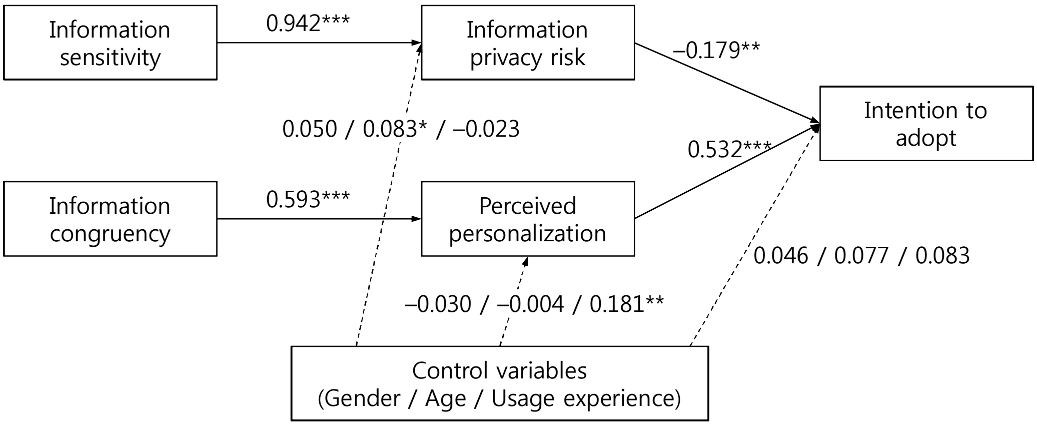
Structural Model Assessment

We conducted hypothesis tests by estimating the structural model and examining the results. First, the model fit was examined. The relative chi-square value (= 1.88) is sufficiently low, indicating an acceptable fit. Fit indices (CFI = 0.95, NFI = 0.90, TLI

(NNFI) = 0.94) and RMSEA (= 0.07) also satisfies common criteria. Therefore, the results establish a satisfactory level of fit between the model and the data.

Next, we provide the test results of the hypothesis based on the structural model estimation. Figure 2 and Table 5 show the results of estimation and hypothesis testing. Figure 2 and Table 5 include standardized path coefficients and unstandardized path coefficients, respectively. First, we consider the effects of the information attributes. The sensitivity of information is found to have a positive effect on information privacy risk with a standardized coefficient of 0.942 ($p < 0.001$), supporting Hypothesis 1. The congruency of information is found to increase perceived personalization with a standardized coefficient of 0.593 ($p < 0.001$). Thus, Hypothesis 2 is also supported.

The results reveal significant effects of the two determinants of the intention to adopt a smart product, information privacy risk and perceived personalization. Information privacy risk has a negative effect on the intention (standardized coefficient = -0.179, $p < 0.01$), validating Hypothesis 3. Perceived personalization is found to influence the intention positively (standardized coefficient = 0.532, $p < 0.001$), supporting Hypothesis 4. Therefore, all of the four hypotheses included in the research model are supported.



Note: * p < 0.1, ** p < 0.01, *** p < 0.001

Figure 2: Structural Model with Standardized Coefficients

Table 5: Path Model Results

Path	Unstandardized Coefficient	Standard Error	*t*-value	*p*-value	Hypothesis Test Result
Information sensitivity → Information privacy risk	1.014	0.093	10.871	< 0.001	H1 supported
Information congruency → Perceived personalization	0.501	0.069	7.313	< 0.001	H2 supported
Information privacy risk → Intention to adopt	-0.197	0.074	-2.655	0.008	H3 supported
Perceived personalization → Intention to adopt	0.719	0.106	6.749	< 0.001	H4 supported
Gender → Information privacy risk	0.106	0.093	1.138	0.255	Control variables
Age → Information privacy risk	0.007	0.004	1.873	0.061	
Usage experience → Information privacy risk	-0.034	0.066	0.511	0.609	
Gender → Perceived personalization	-0.052	0.113	-0.461	0.645	
Age → Perceived personalization	0.000	0.005	-0.068	0.946	
Usage experience → Perceived personalization	0.218	0.080	-2.713	0.007	
Gender → Intention to adopt	0.106	0.149	0.709	0.478	
Age → Intention to adopt	0.007	0.006	1.196	0.232	
Usage experience → Intention to adopt	0.136	0.107	-1.270	0.204	

Finally, we find some path coefficients involving the control variables are significant. The path between age and information privacy risk is weakly significant ($p < 0.1$), indicating that age increases information privacy risk. Further, electric toothbrush usage experience has a positive effect on perceived personalization ($p < 0.01$), suggesting that those consumers who have used electric toothbrushes evaluate personalization of the smart toothbrush more positively than those who have not. Lastly, we find no significant effect of gender.

DISCUSSIONS AND CONCLUSIONS

In this study, we investigated consumers' intention to adopt smart products. Drawing on previous studies on smart products and privacy literature, we proposed a research model that explains factors influencing consumers' intention to adopt smart products, and empirically tested the model using data from an online survey of consumers. Overall, the analysis results support the research hypotheses.

The current study has several implications. First, this study contributes to emerging research stream on smart products by exploring consumers' adoption decision of smart products. The results suggest that consumers' adoption decision is guided by the evaluation of the tradeoff between the benefit and cost related to their use of smart products. Specifically, the results show that personalization offered by smart products is a major benefit while information privacy risk is a critical cost factor in smart product usage.

The results also have important implications for firms that intend to capitalize on smart products. They need to communicate with consumers regarding enhanced value proposition of smart products, more specifically, personalization based on the capability of adaptability, to facilitate their adoption of the products. At the same time, they need to bear in mind that information privacy risk plays a critical role in consumers' adoption decisions, and thus should be addressed effectively. This may be a challenging task because the privacy issue has been rarely an business issue for the firms providing physical products. Relatedly, Porter and Heppelmann [23] suggest that firms should carefully decide which information to collect, secure, and analyze to maximize the value of their smart product offerings and how to manage ownership and access rights to the information.

Our results imply that the sensitivity and congruency of information should be important criteria in deciding which information to collect. We found that the attributes of personal information are determinants of consumers' risk-benefit assessment in their privacy calculus. The sensitivity of information increases information privacy risk while the congruency of information enhances perceived personalization. Further, because the sensitivity and congruency of information influence the risk-benefit assessment through perception about the attributes by consumers, it would be also important for firms to communicate with consumers effectively to mitigate their perception of the sensitivity of the information to be requested and to enhance their perception of the congruency of the information.

Although this study offers the above significant implications, there is a need for future research involving various smart products in terms of price and usage frequency, because the amount of benefit consumers expect from a smart product may be an increasing function of price and the amount of information collected is likely to be an increasing function of usage frequency. Further, regarding the impacts of the information attributes, our study measured the sensitivity and congruency for the aggregate information items collected in the course of the smart toothbrush usage. Therefore, overall sensitivity and congruency were considered in our empirical approach. However, each of the two attributes varies at the information item level. It would be an interesting venue for future research to study user perception on various, specific information items to be collected potentially could generate valuable implications to guide firms' decisions about which information to collect.

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