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User acceptance of smart home services:
An extension of the theory of planned behavior

Abstract

Purpose: This study develops a comprehensive research model that can explain potential customers' behavioral intentions to adopt and use smart home services.

Methodology: This study proposes and validates a new theoretical model that extends the theory of planned behavior (TPB). Partial least squares analysis (PLS) is employed to test the research model and corresponding hypotheses on data collected from 216 survey samples.

Findings: Mobility, security/privacy risk, and trust in the service provider are important factors affecting the adoption of smart home services.

Practical implications: To increase potential users' adoption rate, service providers should focus on developing mobility-related services that enable people to access smart home services while on the move using mobile devices via control and monitoring functions.

Originality/Value: This study is the first empirical attempt to examine user acceptance of smart home services, as most of the prior literature has concerned technical features.

Keywords: smart home service; theory of planned behavior; automation; mobility; interoperability; security/privacy risk; physical risk; trust in service provider

1. Introduction

In a traditional home, appliances are operated separately and locally. Residents control each device by pushing buttons or flipping switches. However, network devices have proliferated in the new environment of ubiquitous computer technology. Consequently, the "smart home" concept has received considerable attention over the last decade. A smart home is based on the "use of information and communication technology (ICT) in the home to facilitate the interoperability of household products and services in a built entity" (Peine, 2008, p. 514). Thus, a home is no longer a place where a number of appliances conduct isolated tasks; instead, a home has a distributed system with many entities that function together. Therefore, a smart home contains technology such as electrical equipment automation, remote lighting/power control, and tele-monitoring (Luor *et al.*, 2015). Smart home service users can easily access the system, control home appliances, and ensure the safety of home and family.

Studies have forecasted rapid growth in the smart home market because of the value of the smart home concept to users, suggesting that the market will have expanded threefold by 2020 (M2M, 2013; Marketsandmarkets, 2011). Additionally, recent market research predicted that the smart home market will grow by 17% annually between 2015 and 2020 and reach a value of US$58.68 billion (Marketsandmarkets, 2015). Global high-tech companies such as Google, Amazon, and Samsung Electronics have been commercializing smart home products and services since 2014 to take advantage of this sizeable emerging market.

Despite the early appearance and positive prospects of smart home services, they have not yet been widely adopted. One reason is that the related technologies enabling the services have been unavailable or pending commercialization; another reason is that research into smart home services has relied mainly on underlying technologies such as sensing, actuation, and networked devices. Thus, few studies have considered the services' user acceptance or behaviors, although such studies are crucial for the successful adoption and rapid diffusion of smart home technology. The smart home concept has been discussed from mostly engineering or technological perspectives (Kühnel *et al.*, 2011; Li and Yu, 2011; Reinisch *et al.*, 2011). The lack of empirical studies on user behavior and the business aspects of smart home services has meant that the adoption and diffusion of services have not been adequately addressed.

Accordingly, this study develops a comprehensive model to investigate the facilitators and barriers of smart home services. This study seeks to further our understanding of the adoption of smart home services by applying the theory of planned behavior (TPB), a widely used acceptance theory in the field of information technology. The TPB is useful in the empirical investigation of user perceptions of new technologies. Moreover, to extend the TPB, this study proposes six exogenous TPB variables that reflect usability, the potential risks of smart home services, and reliable service providers. Based on Wu *et al.* (2007) and Chan *et al.* (2009), this study suggests automation, mobility, and interoperability as three variables that are related to the usability of smart home services. Additionally, this study includes potential users' risk perceptions and trust in service providers as exogenous variables to capture the sacrifice and reliability aspects of using smart home services.

2. Smart home services

Commercial and academic interest in smart homes has grown substantially since the 1980s. Government and research organizations in Japan, the UK, and the US have invested in research and have conducted studies on the development of smart home services (Chan *et al.*, 2009). Various similar concepts (e.g., home automation, networked homes, ubiquitous homes, and intelligent homes and interactive homes) have emerged, and promising service types targeting specific user groups such as the elderly or convalescents have also have been introduced (Friedewald *et al.*, 2005).

A smart home can be defined as a residence equipped with a communication network, high-tech household devices, appliances, and sensors that can be remotely accessed, monitored, and controlled and that provide services responding to the residents' needs (Balta-Ozkan *et al.*, 2013; Reinisch *et al.*, 2011). The basic smart home architecture is shown in Figure 1 (Wu *et al.*, 2007). First, many kinds of home appliance are connected by an internal home network. Second, mobile devices communicate with stationary devices in the home via a telecommunications network and a home gateway. Third, cloud servers for smart home service providers, which collect and analyze data from home devices and mobile devices for interactive and automated services, are linked through the telecommunications network.

<Insert Figure 1 about here>

Prior studies have proposed various types of smart home service. Adami *et al.* (2003) suggested a wrist device that monitors users' lifestyles such as their time spent in and out of bed. Andoh *et al.* (2004) explained the features of a biometrics monitoring system that checks vital signs such as pulse and respiration. The lifestyle monitoring system in Perry *et al.* (2004) monitors users' location and current activity. Kidd *et al.* (1999) proposed a smart home system that guides users to specific radio-frequency (RF) tagged objects and helps them find lost items. Reinisch et al. (2011) studied energy efficiency in future smart homes by tracking users. Boman *et al.* (2007) suggested intruder motion detectors for brain-injury patients. More recently, Balta-Ozkan *et al.* (2013) surveyed smart home services and case studies undertaken in the literature and grouped them into three broad categories: lifestyle support, energy consumption and management, and safety.

The research has suggested the principles and challenges of and recommended approaches to smart home services. However, most approaches are associated with the experimental projects outlined earlier, and they typically assume a technology-based perspective (Harper, 2006). To motivate individuals to adopt smart home services, discussions on user behaviors and the market environment are required. Service providers must satisfy real user needs to enable broad diffusion and successful adoption of the services. Capturing these real user needs calls for an analysis of the factors affecting user behavior concerning service adoption.

3. Theoretical background

The theory of planned behavior (TPB), an extension of the theory of reasoned action (TRA) developed by Fishbein and Ajzen (1975), asserts that the most important determinant of behavior is behavioral intention. The TPB takes into account situations where one may not have complete volitional control over behavior and adds a perceived behavioral control (PBC) construct. In the TPB model, a person's actual behavior when performing a certain action is directly influenced by his or her behavioral intention and determined by three kinds of specific belief about the behavior: attitude, subjective norm, and PBC. According to Ajzen (1991), behavioral intention is an indication of the strength of a person's willingness to try to perform a certain behavior. Attitude is defined as the degree to which a person makes a favorable or unfavorable assessment regarding the behavior in question. Subjective norm denotes the perceived organizational or social pressure to perform or not perform the behavior in question. The third antecedent of behavioral intention is the degree of PBC, reflecting a person's perception of the ease or difficulty of performing the behavior, which is assumed to consider past experience and anticipated obstacles and impediments. Ajzen (1991) also stated that the relative importance of attitude, subjective norm, and PBC for predicting intention varies across behaviors and situations. Thus, one, two, or all three predictors may significantly impact an intention.

The TPB has been applied to various issues, such as physical activities, quitting cigarette smoking, blood donation, complaining, drinking problems, and leisure behavior (Kalafatis *et al.*, 1999; Kang *et al.*, 2006). Especially over the past few decades, many information system (IS) adoption studies have used the TPB as a basic theoretical model for spreadsheets (Mathieson, 1991), computer resource centers (Taylor and Todd, 1995), electronic commerce services (Bhattacherjee, 2000), and mobile commerce (Pedersen, 2005). Moreover, by adding moderating factors, the TPB has influenced the formation of the technology acceptance model (TAM), the unified theory of technology acceptance, and several studies on extended models (Curras-Perez *et al.*, 2014; Gamal Aboelmaged, 2010; Zhang and Aikman, 2007).

4. Research model and hypothesis development

A theoretical model is presented in Figure 2. This model extends the TPB by defining antecedents reflecting usability, the potential risks of smart home services, and reliable service providers in terms of attitude, subjective norm, and PBC. This study defines each of the constructs and develops a theoretical rationale for the causal relationships in the model. Demographic conditions may influence user behavior in smart home service adoption. Thus, the model considers gender, income, and type of residence as control variables to check the exact degree of the research variables' effects.

<Insert Figure 2 about here>

4.1. Attitude and intention to use

Different theoretical models such as the TRA, the TPB, and the TAM have confirmed that attitude is a key antecedent of the intention to engage in a particular behavior (Ajzen and Fishbein, 1980). Further, many prior studies on technology adoption consider the concept of attitude, reflecting favorable or unfavorable feelings about particular behavior, as an important determinant influencing the intention to use (Bauer *et al.*, 2005; Zhou *et al.*, 2007). Ho Cheong and Park (2005) showed that attitude toward the mobile Internet positively affected the behavioral intention to use it. Hsiao (2013) verified that user attitude toward android devices had a positive impact on user intention to choose android smartphones. Kranz *et al.* (2010) found that the attitude toward using a smart meter, the representative smart home device, had a positive effect on the intention to use it. Based on such prior research, this study defines attitude as the perceived level of positive feelings toward the use of smart home services. Thus, this study's first hypothesis is as follows:

> ***H1***. *Attitude toward smart home services is positively associated with the intention to use them.*

4.2. Subjective norm and intention to use

In general, the potential users of any technology at the early stage of diffusion lack enough information to make a decision about using it. Therefore, an individual's adoption decision about new emerging technology may be influenced by others' opinions or suggestions within a social system (Hu *et al.*, 2003). This study incorporates the social context in the research model by including subjective norm, defined by Fishbein and Ajzen as a "person's perception that most people who are important to him think he should or should not perform the behavior in question" (1975, p. 302). The positive relationship between subjective norm and intention to use has been found in many prior studies (Schepers and Wetzels, 2007; Taylor and Todd, 1995; Venkatesh and Davis, 2000). Schierz *et al.* (2010) identified the importance of subjective norm concerning attitudes towards using mobile payment services. Chi *et al.* (2011) found that consumer subjective norm positively affected behavioral intention to purchase smartphones. Sun *et al.* (2013) showed that subjective norm was positively associated with mobile health service adoption intention.

According to Forrester (2014), only 1 to 2% of consumers have connected devices to control lighting, climate, energy, appliances or have a home monitoring solution in place, indicating that the smart home service market is at the very early stage. As a result, potential customers may be motivated to accept smart home services through important referents' opinions or community norms. Therefore, this study defines subjective norm as potential smart home service users' perception that most people who are important to them think they should use smart home services. The following hypothesis is thus proposed:

H2. *Subjective norm is positively associated with the intention to use smart home services.*

4.3. Perceived behavioral control and intention to use

The TPB proposed PBC as a new determinant of behavioral intention. The purpose of PBC was to remove the limitations of the TRA by incorporating behavior over which people have incomplete volitional control (Ajzen, 1991). Since then, a number of empirical studies have identified a relationship between PBC and intention (Madden *et al.*, 1992; Sparks and Shepherd, 1992). In particular, Taylor and Todd (1995) defined PBC in terms of IT usage and the internal and external limitations a person may encounter when performing certain activities. The authors then found that PBC was positively related to behavioral intention. Kim (2010), Deng *et al.* (2014), and Lu *et al.* (2014) showed that PBC positively influenced the intention to use mobile data services. Wunderlich *et al.* (2012) suggested that the higher the PBC, the higher the continuing usage of smart meters; thus, the authors confirmed a positive relationship between PBC and the intention to use such meters. In this study, PBC refers to potential users' perception of how easy or difficult it would be to use smart home services. Thus, this study proposes the following hypothesis:

> ***H3***. *Perceived behavioral control is positively associated with the intention to use smart home services.*

4.4. Exogenous variables

4.4.1. Automation

Automation is defined as the "execution by a machine agent (usually a computer) of a function that was previously carried out by a human" (Parasuraman and Riley, 1997). The popularity of automation has been widely accepted in smart homes in recent years owing to its improved affordability and simplicity through wider connectivity (Luor *et al.*, 2015). In this context, Noh and Kim (2010) defined the digital home as a fully automated residence based on home appliances and computing devices. Augusto and Nugent (2006) argued that artificial intelligence could improve the functionality of smart homes when the homes realize the long-standing dream of proactively helping their residents in an intelligent way. Luor *et al.* (2015) verified the correlation between the usefulness of the smart home automation function and residents' attitudes to it. Thus, this study defines automation as smart home service execution without human intervention, and proposes the following hypothesis:

> ***H4***. *Automation is positively associated with attitudes to using smart home services.*

4.4.2. Mobility

Mobility refers to the capability to access services while on the move using devices such as laptops, smartphones, and mobile phones (Choi *et al.*, 2014; Lyytinen and Yoo, 2002). Mobility has been a core function of service access since mobile devices began being used to access the Internet, transmit data, and execute mobile applications. Choi et al. (2014) examined the relationship between mobility and consumers' attitudes toward mobile recommendation systems and verified that mobility was positively associated with attitude. Gunawardana and Ekanayaka (2009) found that the perceived mobility of mobile learning (m-learning) services positively influenced users' attitudes. Further, Park and Joon Kim (2013) explored the mobility of long-term evolution (LTE) services as significant determinants of perceived usefulness and system/service quality.

Moreover, mobile devices seem to be an important interactive user interface for smart home systems, with an increasing number of sensors and multi-touch screens (Kühnel *et al.*, 2011). Koskela and Väänänen-Vainio-Mattila (2004) argued that users preferred a remote control for instant control in a smart home over lamps, curtains, and information appliances. Roduner *et al.* (2007) suggested that user interfaces on a mobile device were an optimal solution for operating a range of home appliances. In this study, mobility is defined as the ability to access smart home services while on the move by using mobile devices. Thus, this study proposes the following hypothesis:

H5. *Mobility is positively associated with attitudes toward using smart home services.*

4.4.3. Interoperability

Devices and systems from different vendors need to interoperate in a smart home environment. Interoperability refers to the ability of subsystems, applications, and services made by various manufacturers to work together reliably (Geraci *et al.*, 1991). The interoperability of smart home services can be achieved in two ways—by adopting universal standards for a communication protocol for smart home devices or by developing a gateway that acts as an interpreter among different smart home devices and protocols (Balta-Ozkan *et al.*, 2014).

Many studies have verified the importance of interoperability for adopting new IT services. Pagani (2004) showed that compatibility was a factor influencing the perceived usefulness of mobile multimedia services. Yang *et al.* (2016) confirmed the positive relationship between technical compatibility and users' perceived usefulness of wearable devices. Esteves and Curto (2013) found that compatibility with existing systems such as enterprise resource planning (ERP), customer relationship management (CRM), and product lifecycle management (PLM) was a significant factor in attitudes toward big data solutions. Thus, this study defines interoperability as the degree to which smart home service devices from different vendors interoperate with each other and therefore proposes the following hypothesis:

H6. *Interoperability is positively associated with attitudes toward using smart home services.*

4.4.4. Security/privacy risk and physical risk

Smart home systems collect data about residents' lifestyles, such as movement, energy use, and purchase preferences, in order to support them effectively. Consequently, these systems face the challenge of ensuring the safety of personal data (Balta-Ozkan *et al.*, 2014). Kalakota and Whinston (1997) defined security risk as a "circumstance, condition, or event with the potential to cause economic hardship to data or network resources in the form of destruction, disclosure, modification of data, denial of service, and/or fraud, waste, and abuse." Security risk includes the risk of the violation of a user's privacy. In this study, therefore, security/privacy risk refers to smart home service users' fear that their personal data will be leaked or that their smart home systems will be hacked by criminals. In this regard, Lee (2009) found that security/privacy risk negatively influenced attitudes toward the use of online banking. Chou and Yutami (2014) also showed that perceived risk, of which privacy and safety concerns are significant antecedents, negatively affected attitudes toward smart meter adoption.

In addition to security/privacy risk, physical risk should also be considered. Jose and Malekian (2015) argued that a simple device such as a fluorescent lamp that is connected to a smart home system could cause physical harm (e.g., shattered glass, fire outbreak, or mercury poisoning) to residents. Further, FTC (2015) released a report describing the physical risk of smart homes and gave examples such as home security systems turned off by intruders and the hacking of home healthcare services. This study defines physical risk as the possibility that smart home service users could harm themselves or others through hacking, misuse, or malfunction. Based on the foregoing literature review, this study proposes the following hypotheses:

H7. *Security/privacy risk is negatively associated with attitudes toward using smart home services.*

H8. *Physical risk is negatively associated with attitudes toward using smart home services.*

4.4.5. Trust in smart home service providers

Trust has long been regarded as a catalyst for buyer–seller transactions that reduces uncertainty or vulnerability in exchanges (Doney and Cannon, 1997; Luhmann, 1979; Pavlou, 2003; Ring and Van de Ven, 1994). Within the IS field, trust has been highlighted as an important factor in influencing consumer behavior. For example, Keen *et al.* (1999) explained the strategic implications of trust for consumer–marketer relationships in e-commerce. Gefen (2000) verified that trust was instrumental in the acceptance of Internet technologies. Hsu *et al.* (2014) found that trust in sellers was positively related to the perceived quality of and satisfaction with sellers in online group-buying transactions. Researchers have also integrated trust with the TPB, finding that trust was an important antecedent of attitude, subjective norm, and PBC in online services (Lee, 2009; Wu and Chen, 2005).

Trust in service providers is also a significant issue in the smart home industry. A CNET (2014) article entitled “How Big Brother's going to peek into your connected home” argued that potential users feared smart home business expansion and data collection from big IT companies such as Google. Luor *et al.* (2015) showed the positive relationship between smart home residents’ perceived trust and attitudes toward smart home services.

This study defines trust in service providers as smart home service users’ belief that selling parties are honest, dependable, and reliable and therefore proposes the following hypotheses to identify the positive relationship between trust and the three TPB components:

H9a. *Trust in service providers is positively associated with attitudes toward using smart home services.*

H9b. *Trust in service providers is positively associated with the subjective norms that affect the use of smart home services.*

H9c. Trust in service providers is positively associated with the perceived behavioral control of smart home services.

5. Research method

5.1. Data

This study conducted an online survey to evaluate the research model. Data collection was subcontracted to a professional survey company in Korea. To test the behaviors of potential smart home service customers, the company randomly selected people over the age of 16 who had not used smart home services from the firm's member database. During two weeks in October 2015, the company distributed a questionnaire to 400 members and collected 238 responses. A response rate is crucial for the validity of research results. According to Baruch (1999), a reasonable response rate in academic studies is about 60% (+/-20), so the response rate of this study is adequate (59.5%). After missing or erroneous data were removed, 216 samples were finally retained for study. Hair *et al.* (2011) suggested that the minimum effective sample size is 10 times the largest number of formative indicators or the highest number of structural paths directed at a particular latent construct. The highest number for our research model is six, so the minimum sample size is 60. Thus, the sample size of this study is sufficient for the analysis. Detailed descriptive statistics for the respondents' demographic characteristics are presented in Table 1. The samples' demographic characteristics resemble the Korean Population Statistics collected for Koreans aged from 10 to 69 in January 2015, in which 50% of the population was female, and the nation was broken down into the 10 to 19 age group (13.0% of the population), 20 to 29 age group (17.1%), 30 to 39 age group (20.8%), 40 to 49 age group (21.2%), 50 to 59 age group (17.5%), and 60 to 69 age group (10.4%).

<Insert Table 1 about here>

5.2. Instrument development

All measurement items in this study were developed based on prior studies and checked for reliability and validity. Thirty measurement items describe 10 latent constructs: automation, mobility, interoperability, security/privacy risk, physical risk, trust in service providers, attitude, subjective norm, PBC, and intention to use. Table 2 shows the measurement items used in the study.

<Insert Table 2 about here>

6. Data analysis and results

6.1. Measurement model

This study employed partial least squares (PLS) methodology with Smart PLS 2.0 to test the proposed model and the corresponding hypotheses. PLS is appropriate given the sample size (n=216), the focus on each path coefficient, and the focus on variance explained rather than overall model fit (Chin *et al.*, 2003).

Confirmatory factor analysis was conducted to investigate the convergent validity of each construct. Table 3 shows the cross-loadings of all items and indicates that they load highest on their respective construct. Table 4 summarizes the construct statistics. Convergent validity was assessed by examining the factor loadings for each item in the measurement model, the significance level for each loading, the reliability, and the average variance extracted (AVE) for each construct. All factor loadings exceed 0.60, the minimum requirement for the convergent validity of constructs (Anderson and Gerbing, 1988). Cronbach's alphas for all 11 constructs are above the recommended level of reliability (0.70). The AVE for each construct exceeds 0.50 (Fornell and Larcker, 1981) and thereby establishes convergent validity.

<Insert Table 3 about here>

<Insert Table 4 about here>

When examining discriminant validity, the square root of the AVE for each construct should be greater than the correlation values between any two constructs. The inter-construct correlation matrix (see Table 5) demonstrates that all values meet these recommendations for discriminant validity.

<Insert Table 5 about here>

6.2. CMV and GoF

When a study uses self-reported data from a survey, common method variance (CMV) should be considered. CMV refers to "variance that is attributable to the measurement method rather than to the constructs the measures represent" (Podsakoff *et al.*, 2003, p. 879). Rigorous research design and data collection can avoid CMV problems. However, rigor in research design and data collection is complex, and most studies apply several statistical methods to test CMV during the data analysis procedure. According to Podsakoff *et al.* (2003), Harman's single-factor test or a discriminant validity table are examples of such statistical methods. According to the results of the single-factor test, seven factors were found, and the first factor's variance was lower than 50%. Table 5 shows that negative correlations among constructs are observed; therefore, the data of this study are not subject to a CMV problem.

Typically, a PLS study does not require model fit. However, Tenenhaus *et al.* (2005) currently provide an alternative way to assess the GoF (Goodness of Fit) of a PLS model. The GoF can be calculated with AVE and R square of the structural model, and it is recommended that the value be over 0.36 (Wetzels *et al.*, 2009). The GoF of this study is 0.57; therefore, the model is valid.

6.3. Hypotheses testing

This study employed a bootstrapping technique within Smart PLS that used randomly selected subsamples to generate t-statistics to indicate the significance of model paths. The structural equation model results are summarized in Figure 3. Of the 11 proposed hypotheses, nine are supported. All three TPB constructs (i.e., attitude, subjective norm, and PBC) are significant mediating factors that influence intention to use (H1, β=0.37, t-value=6.30, $p<0.001$; H2, β=0.33, t-value=5.71, $p<0.001$; H3, β=0.25, t-value=5.01, $p<0.001$) and explain 64.0% of the variance. Among the antecedents of attitude, mobility and interoperability show a significant positive impact on attitude but not automation. Hence, H5 and H6 are supported while H4 is not (H5, β=0.25, t-value=2.53, $p<0.01$; H6, β=0.19, t-value=2.13, $p<0.05$). Security/privacy risk has a negative effect on attitude (β=-

0.13, t-value=1.99, $p<0.05$), while the path from physical risk to attitude is insignificant. Thus, H7 is supported, but H8 is not. Trust in service provider is a significant factor that influences attitude, subjective norm, and PBC (H9a, $\beta=0.20$, t-value=2.80, $p<0.01$; H9b, $\beta=0.57$, t-value=10.00, $p<0.001$; H9c, $\beta=0.39$, t-value=6.99, $p<0.001$). The R square of intention to use is 64%, and the other mediators are 47% (Attitude), 32% (Subjective norm), and 15% (Perceived behavioral control). Two control variables (income and residence type) were not significant, but gender had a negative impact on intention to use. This implies that females have a stronger intention to use smart home services. Because the research model was extended based on the TPB, this study did not test the direct relationships between the independent variables and dependent variables. To verify the direct effects of independent variables, a full model was tested following the previous analysis procedure, but no significant or strong relationship was observed.

<Insert Figure 3 about here>

6. Discussion

The objective of this paper was to develop a comprehensive research model that can explain the potential customers' behavioral intentions to adopt and use smart home services. For this purpose, this study employed the TPB and enhanced it by proposing six exogenous variables that reflect the functionality of smart home services (i.e., automation, mobility, and interoperability), risk factors (i.e., security/privacy risk, and physical risk), and trust in service providers.

Several findings flow from this research. As expected, the results of the study were consistent with the original TPB, showing that attitude, subjective norm, and PBC are the three key factors that affect the intention to use smart home services. This study confirmed that attitude is a key factor that influences behavioral intention, while the strong effect of subjective norm on adoption intention is surprising because, in prior studies, this factor was found to have a relatively weak or insignificant impact on intention (Lee, 2009; Taylor and Todd, 1995; L. Wu and Chen, 2005). It can be inferred that, as smart home services are in an early stage of diffusion, potential users have little experience and are willing to rely on the opinions and behaviors of others. Further, the positive relationship between (PBC) and intention to use demonstrated that, when potential users perceive more controllability than obstacles, they feel able to adopt smart home services.

Interestingly, among the three antecedents of attitude that reflect service usability, mobility was shown to have a stronger effect on attitude than interoperability. This result indicates that, compared with a ubiquitous service from different vendors, potential users recognize more value in remote access functionalities such as remote control, management, and monitoring without time and location restrictions based on networking between mobile devices and home appliances. In fact, relatively simple features such as remote control, management, and monitoring are the most popular smart home service types offered by telecom service providers and device manufacturers. For example, Samsung electronics categorized its smart home services as “customized device control,” “home view,” and “device management” when the company launched them at the CES 2014 trade show. Further, LG U Plus, a telecommunication service provider in South Korea, provides 12 smart home services that all fall within the categories of remote control, management, or monitoring services (e.g., remote lighting control, remote stove control, a door-opening alarm, and real-time energy consumption management). Thus, it is reasonable to infer that people have relatively little opportunity to perceive direct benefits from interoperability because of a lack of commercialized smart home services and technical problems such as standardization.

Automation, which represents a long-standing vision of proactively assisting smart home residents, had an insignificant influence on attitude. One possible reason is that users may want controllability rather than automation. The home is a private place where individuals desire security and control. The current model of smart home services could also be one reason that automation is less important than other factors. The automation function that service providers offer is limited or resembles rule-based automation. Therefore, consumers may sense that automation is not perfect or necessary. The most persuasive reason is the variety among user contexts and environments. For instance, different housing architectures may be associated with the importance of automation. A single-family house is typically larger than an apartment/multi-family house and may have a duplex structure for one household. According to the Korean Statistical Information Service, the last census (2010) found that the average living area per person in an apartment was less (24.6 m^2) than that of a single-family house (26.2 m^2). Additionally, recently built apartment homes already contain home network systems with home pad interfaces on the walls that provide basic control and monitoring features, such as indoor temperature control, lighting control, car entry alarm, and remote door opening. Thus, apartment/multi-family house residents may have less need to use automated functions because they can easily control each home device manually or through a single home pad. For single-family home residents, however, automation can play an important role by solving the inconvenience of controlling, managing, and monitoring home devices in a relatively large space. According to the hypothesis test results, the t-value of H4 is close to the cutoff value of 95% confidence in a one-tailed test. This result also supports the premise that respondents' characteristics may influence the role of automation in attitudes towards smart home services.

In addition, this study verified that security/privacy risk negatively affected attitude, although physical risk did not. Indeed, personal security and privacy has become an issue of global regulation. For example, a poll by market research firm (GFK, 2014) found that almost nine out of 10 people said that they were at least "a little" concerned about the safety of their personal information. Moreover, over half of the respondents said that the U.S. government was not doing enough to protect their data, and almost 80 percent said that strong regulations should govern how data brokers and others can repurpose personal information. Thus, this study's result suggests that potential users of smart home services already recognize the risk of personal data leakage and misuse. However, potential users do not perceive a serious physical risk from hacking and trespass. The reason for this could be twofold. First, until now, the risk of physical damage for smart home service users has not been publicized because the service diffusion rate is low. Second, many houses in South Korea are already equipped with fire extinguishers and security facilities such as smart card door access and 24-hour CCTV.

This empirical analysis showed that trust in service providers should be considered an important antecedent of the three determinants of intention to use: attitude, subjective norm, and PBC. This result indicates that potential users rely not only on technology-based features but also on emotionally based trust in order to form their behavioral intentions. Specifically, trust in service providers explained only 32.1% of the total variance in subjective norm, indicating that trust in service providers will strongly enhance potential users' normative beliefs about the advice of referents such as friends, peers, and superiors.

Although gender was considered as a control variable in this study, the result shows that gender should be addressed in relation to smart home service adoption. According to the results, females had greater intention to use the services than males. Because women are typically more concerned with the household, acceptance criteria and behaviors may differ according to gender. Additionally, in the case of married couples, women typically decide the usage level and service provider; therefore, their perspectives may be paramount.

7. Conclusion

This study makes several contributions to theory. To begin, this is the first empirical study to examine user acceptance of smart home services, which are at an early stage of diffusion. Most of the literature related to smart home services has concerned technical architecture (Perumal *et al.*, 2008; C.-L. Wu *et al.*, 2007), a specific device, a service such as a smart meter and energy management (Balta-Ozkan *et al.*, 2014; Chou and Yutami, 2014), and future perspectives based on qualitative research (Chan *et al.*, 2009; Ehrenhard *et al.*, 2014). Second, although many prior studies have used the TPB to predict IS usage (Bhattacherjee, 2000; Mathieson, 1991; Pedersen, 2005; Taylor and Todd, 1995), no research has been conducted to test the role of the TPB in the context of smart home services. This study demonstrates that TPB is a powerful theory for anticipating the behavioral intentions of potential smart home service users by verifying that attitude, subjective norm, and PBC are positively related to the intention to use. Third, this study proposed and validated a new theoretical model by enlarging the scope of the adoption decision not only to include service usability factors (automation, mobility, and interoperability) but also to simultaneously comprise negative factors (security/privacy risk and physical risk) and trust in service providers. Consequently, the empirical results showed that the extended research model has good explanatory power, with an R^2 value (64.3%). This implies that the integration of the TBP and proposed antecedent factors creates a useful framework with a theoretical basis to explain smart home services. Further, this framework can be applied to future studies on the adoption of new convergence services that examine customers' intention to use.

From the practitioner's perspective, this study provides several useful insights for managers who control the development and distribution of smart home services. To increase adoption rates, service providers should focus on developing mobility-related services that enable people to access smart home services while on the move using mobile devices based on control and monitoring functions. Further, service providers should cooperate with mobile application companies, operating system developers, and mobile device manufactures in order to develop novel and desirable applications or to enhance the ease of customer contact through preloaded applications. In addition, the feasibility of developing the before-market with house construction firms should also be reviewed, so that smart home systems that support mobility services are installed when new houses are built. To implement automation services, large-scale investment is required in data centers and cloud/big data solutions in order to analyze residents' lifestyles and interact with their movements or emotional changes. It may also help to secure smart home service users' personal data.

The interoperability of smart home services should be achieved by adopting universal standards for a communication protocol for smart home devices. Alternatively, a standardized gateway that acts as an interpreter among different smart home devices should be developed. Several consortia already exist to solve standardization issues regarding the Internet of things, including the Allseen Alliance, Open Interconnect, the Thread Group, and one M2M. Such organizations must work together at the initial stage to establish an appropriate technical architecture for efficient smart home service implementation. Further, corporate communication units should consider promoting to smart home service providers the need to enhance trust levels. This promotion must contain content about the popular use of smart home services in respectable societies and should explain the ease of use of such services, thereby positively influencing behavioral intentions.

Although the findings of this study provide meaningful insights into the adoption of smart home services, several other issues should be accounted for in future research. First, the data of this study were collected from potential users in South Korea. Further study should test the study's findings in different countries in order to assess the generalizability of the findings. Second, future studies could investigate each service category such as health care, security, and energy management in order to identify differences in the adoption processes. Third, the individual differences of this study's survey respondents were not examined. Future studies could extend and refine the findings by investigating the moderating effects of individual differences such as gender and residence type. However, although this study has some limitations, it nonetheless contributes to a more systematic understanding of smart home service adoption. In this regard, it is hoped that this study helps to provide a foundation for future research on related topics.

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Table 1 Characteristics of the respondents

Characteristics	Respondents (n=216) Number	Percentage
Gender		
Male	111	51.4
Female	105	48.6
Age		
16-19	28	13.0%
20-29	37	17.1%
30-39	45	20.8%
40-49	46	21.2%
50-59	38	17.5%
60+	22	10.4%
Education		
Less than high school	44	20.4%
College or university	150	69.4%
Advanced degree	22	10.2%
Monthly Income($)		
Less than 1,000	23	10.6%
1,000~2,000	41	19.0%
2,000~3,000	58	26.9%
3,000~4,000	30	13.9%
4,000~5,000	18	8.3%
5,000 +	46	21.3%
Occupation		
Official worker	60	27.8%
Service worker	8	3.7%
Professional/Researcher	12	5.5%
Self-employer	14	6.5%
Public service worker	3	1.4%
Student	66	30.6%
Housewife	34	15.7%
Other	19	8.8%
Residence Type		
Apartment/Multi-family house	114	52.8
Single house	102	47.2

Table 2 Survey items used in this study

Construct	Item No.	Measurement items	References
Automation	ATM1	It is convenient that smart home services help the residents proactively without human intervention.	(Augusto and Nugent, 2006); (Luor *et al.*, 2015)
	ATM2	It is convenient that smart home services provide auto-adjusted control.	
	ATM3	I can control every electrical apparatus of smart home services through simple operation.	
Mobility	MO1	It is convenient to access smart home services anywhere at any time.	(Park and Ohm, 2014); (Hill and Roldan, 2005)
	MO2	It is convenient to use smart home services while moving from place to place or doing anything else.	
	MO3	Mobility is an outstanding advantage of smart home services.	
Interoperability	INO1	Smart home services are interoperable with existing hardware (smartphone, etc.).	(Bradford and Florin, 2003)
	INO2	Smart home service devices are interoperable with each other.	
	INO3	Smart home services by integrating different device venders do not create problems.	
Security/ Privacy risk	SPR1	I'm worried to use smart home services because other people or organizations may be able to access my account.	(Featherman and Pavlou, 2003); (Xu *et al.*, 2009)
	SPR2	It is risky to disclose personal information to the smart home service provider.	
	SPR3	There will be much potential loss associated with disclosing personal information to the smart home service provider.	
Physical risk	PHR1	Smart home services could lead to some uncomfortable physical side effects due to malfunctions or misuse (smart oven, smart door-lock, smart healthcare, etc.).	(Stone and Grønhaug, 1993)
	PHR2	Because smart home services may not be completely safe, I concern about potential physical risks	
Trust in service providers	TR1	I think smart home services providers are reliable.	(M.-H. Hsu *et al.*, 2014); (Delgado-Ballester, 2004)
	TR2	I think smart home services providers keep promises and commitments.	
	TR3	I think smart home services providers keep customers' best interests in mind	
	TR4	I feel confidence in brand of smart home service providers.	
Attitude	ATT1	It would be a wonderful idea to employ smart home services.	(Bhattacherjee, 2000)
	ATT2	I would have positive feelings toward smart home services.	
	ATT3	It is better for me to employ smart home services, as opposed to other services.	
Subjective Norm	SN1	People who influence my behavior think that I should use smart home services.	(Taylor and Todd, 1995); (Bhattacherjee, 2000)
	SN2	People who are important to me think that I should use smart home services.	
	SN3	People whose opinions are valued to me would prefer that I should use smart home services.	
Perceived Behavioral Control	PBC1	I will be able to adopt smart home services.	(Taylor and Todd, 1995)
	PBC2	Adopting smart home services is entirely within my control.	
	PBC3	I have the resources, knowledge, and ability to adopt smart home services.	
Intention to use	IU1	Using smart home services is worthwhile.	(Davis *et al.*, 1989); (C.-L. Hsu and Lin, 2015)
	IU2	I intend to use smart home services in the future.	
	IU3	I predict I would use smart home services in the future.	

Table 3 Construct cross-loadings

	ATM	MO	INO	SPR	PHR	TR	ATT	SN	PBC	IU
ATM1	**0.904**	0.544	0.492	-0.189	-0.174	0.455	0.446	0.480	0.371	0.456
ATM2	**0.912**	0.579	0.526	-0.169	-0.156	0.450	0.442	0.444	0.343	0.485
ATM3	**0.890**	0.669	0.611	-0.277	-0.183	0.627	0.548	0.623	0.400	0.628
MO1	0.583	**0.926**	0.693	-0.230	-0.231	0.556	0.581	0.537	0.420	0.569
MO2	0.638	**0.937**	0.655	-0.211	-0.225	0.515	0.542	0.504	0.461	0.591
MO3	0.633	**0.904**	0.667	-0.184	-0.223	0.547	0.529	0.509	0.456	0.570
INO1	0.490	0.624	**0.884**	-0.315	-0.134	0.506	0.478	0.484	0.418	0.496
INO2	0.600	0.703	**0.914**	-0.303	-0.192	0.569	0.612	0.549	0.387	0.616
INO3	0.523	0.612	**0.875**	-0.314	-0.189	0.515	0.481	0.421	0.330	0.505
SPR1	-0.218	-0.209	-0.318	**0.896**	0.330	-0.248	-0.293	-0.240	-0.110	-0.248
SPR2	-0.204	-0.171	-0.317	**0.906**	0.338	-0.283	-0.281	-0.304	-0.153	-0.318
SPR3	-0.226	-0.230	-0.302	**0.896**	0.364	-0.272	-0.281	-0.233	-0.166	-0.307
PHR1	-0.184	-0.239	-0.192	0.335	**0.965**	-0.114	-0.156	-0.149	-0.082	-0.169
PHR2	-0.178	-0.227	-0.176	0.403	**0.939**	-0.121	-0.119	-0.110	-0.046	-0.149
TR1	0.477	0.546	0.549	-0.293	-0.156	**0.891**	0.514	0.517	0.328	0.498
TR2	0.539	0.542	0.594	-0.270	-0.155	**0.909**	0.487	0.518	0.402	0.527
TR3	0.563	0.501	0.509	-0.244	-0.064	**0.877**	0.498	0.532	0.384	0.495
TR4	0.485	0.511	0.488	-0.260	-0.061	**0.915**	0.493	0.460	0.283	0.472
ATT1	0.481	0.574	0.548	-0.311	-0.199	0.510	**0.900**	0.586	0.376	0.577
ATT2	0.476	0.530	0.539	-0.275	-0.082	0.488	**0.926**	0.634	0.391	0.651
ATT3	0.512	0.534	0.541	-0.282	-0.123	0.521	**0.911**	0.623	0.379	0.660
SN1	0.539	0.522	0.512	-0.263	-0.124	0.510	0.633	**0.927**	0.450	0.626
SN2	0.558	0.529	0.508	-0.282	-0.106	0.548	0.637	**0.947**	0.434	0.660
SN3	0.534	0.523	0.520	-0.262	-0.160	0.531	0.622	**0.933**	0.419	0.657
PBC1	0.307	0.327	0.303	-0.122	-0.014	0.317	0.303	0.313	**0.858**	0.409
PBC2	0.409	0.465	0.401	-0.185	-0.092	0.370	0.405	0.484	**0.948**	0.538
PBC3	0.401	0.501	0.437	-0.122	-0.074	0.374	0.419	0.447	**0.915**	0.549
IU1	0.528	0.558	0.545	-0.272	-0.175	0.513	0.645	0.662	0.526	**0.950**
IU2	0.580	0.606	0.603	-0.312	-0.127	0.537	0.661	0.680	0.570	**0.965**
IU4	0.569	0.618	0.592	-0.336	-0.178	0.532	0.663	0.631	0.484	**0.935**

Table 4 Loadings of indicator variables

Construct	Items	Factor loading	Std. error	t-value	AVE (>0.5)	Composite Reliability(>0.6)	Cronbach's alpha(>0.7)
Automation	ATM1	0.904	0.016	57.422	0.814	0.929	0.886
	ATM2	0.912	0.015	59.992			
	ATM3	0.890	0.014	63.797			
Mobility	MO1	0.926	0.010	92.081	0.851	0.945	0.912
	MO2	0.937	0.010	97.406			
	MO3	0.904	0.014	65.356			
Inter-operability	INO1	0.884	0.022	40.181	0.794	0.920	0.871
	INO2	0.914	0.011	87.054			
	INO3	0.875	0.019	45.152			
Security/ Privacy risk	SPR1	0.896	0.021	43.669	0.809	0.927	0.882
	SPR2	0.906	0.023	38.720			
	SPR3	0.896	0.019	47.868			
Physical risk	PHR1	0.965	0.068	14.207	0.907	0.951	0.899
	PHR2	0.939	0.093	10.062			
Trust in service providers	TR1	0.891	0.020	45.506	0.807	0.943	0.920
	TR2	0.909	0.012	74.055			
	TR3	0.877	0.019	45.923			
	TR4	0.915	0.014	64.885			
Attitude	ATT1	0.900	0.016	57.453	0.832	0.937	0.899
	ATT2	0.926	0.012	77.854			
	ATT3	0.911	0.011	81.917			
Subjective Norm	SN1	0.927	0.011	86.560	0.875	0.955	0.929
	SN2	0.947	0.008	126.235			
	SN3	0.933	0.010	92.730			
Perceived Behavioral Control	PBC1	0.858	0.032	27.152	0.824	0.933	0.893
	PBC2	0.948	0.007	145.556			
	PBC3	0.915	0.017	54.219			
Intention to use	IU1	0.950	0.006	156.016	0.902	0.965	0.946
	IU2	0.965	0.005	196.510			
	IU3	0.935	0.009	107.428			

Table 5 Correlations of the constructs and square root of AVE

	ATM	MO	INO	SPR	PHR	TR	ATT	SN	PBC	IU
ATM	**0.902**									
MO	0.669	**0.922**								
INO	0.608	0.729	**0.891**							
SPR	-0.240	-0.226	-0.347	**0.900**						
PHR	-0.191	-0.245	-0.194	0.382	**0.952**					
TR	0.576	0.585	0.597	-0.297	-0.123	**0.898**				
ATT	0.537	0.598	0.595	-0.317	-0.146	0.555	**0.912**			
SN	0.581	0.561	0.549	-0.288	-0.139	0.566	0.674	**0.936**		
PBC	0.414	0.482	0.424	-0.159	-0.070	0.392	0.418	0.464	**0.908**	
IU	0.589	0.625	0.611	-0.323	-0.168	0.555	0.691	0.693	0.556	**0.950**

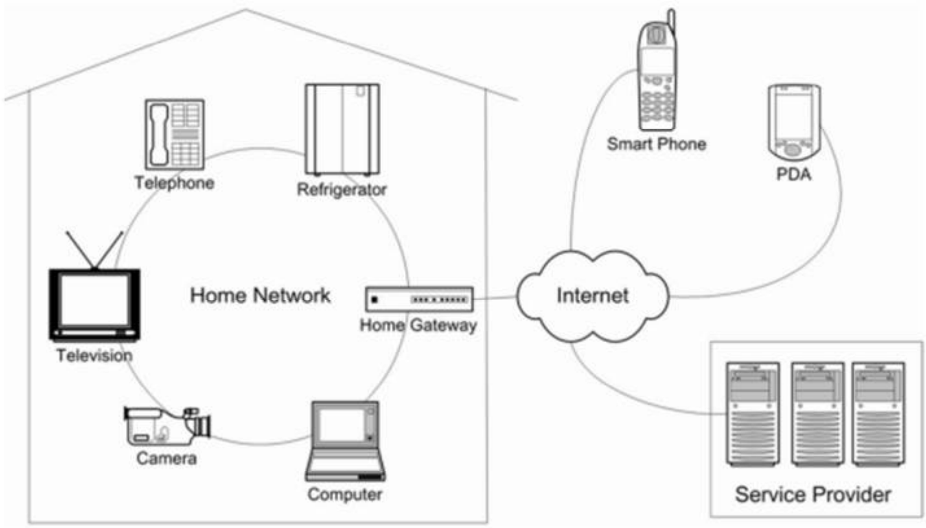

Figure 1 Typical architecture of smart home

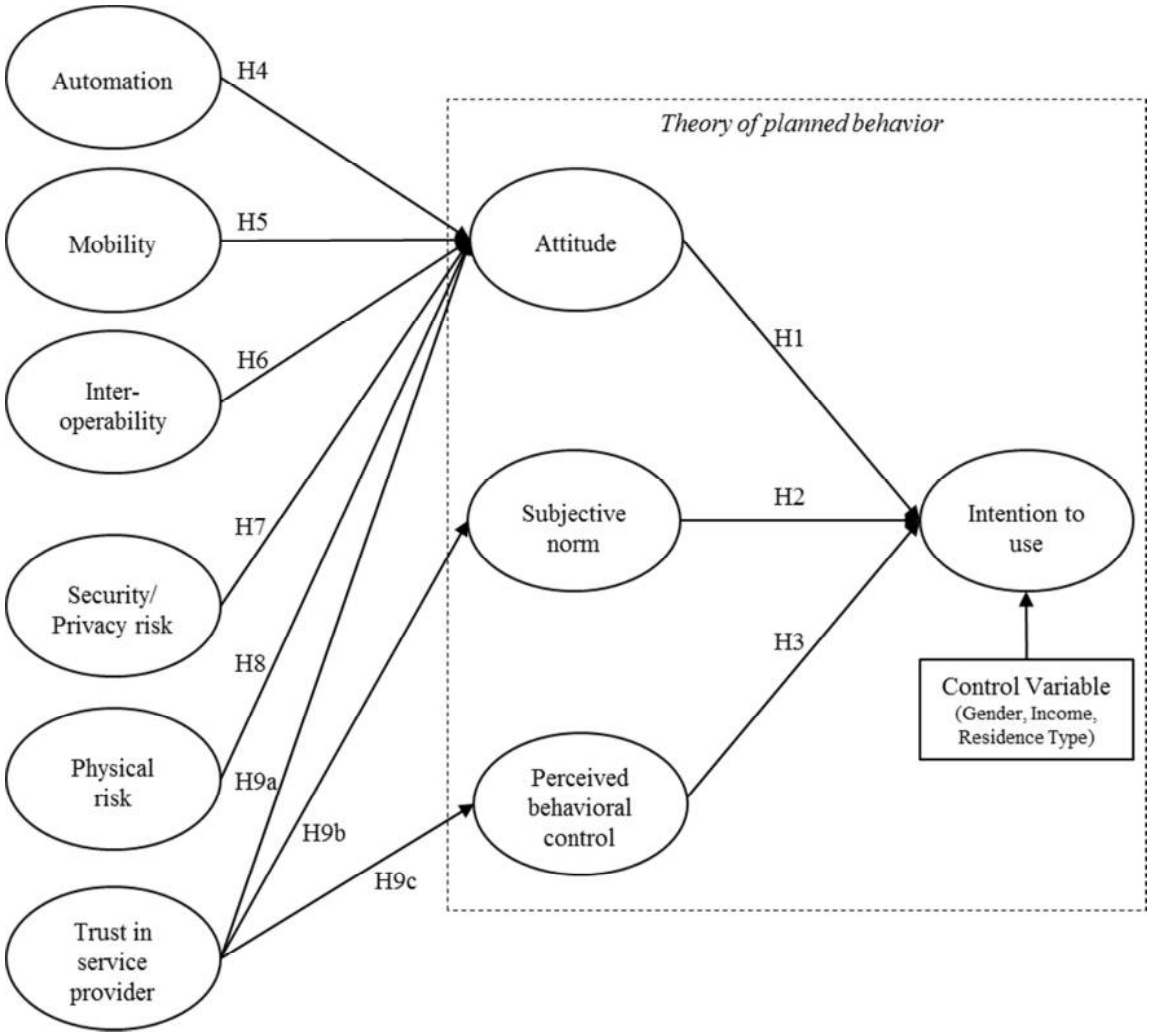

Figure 2 Research model

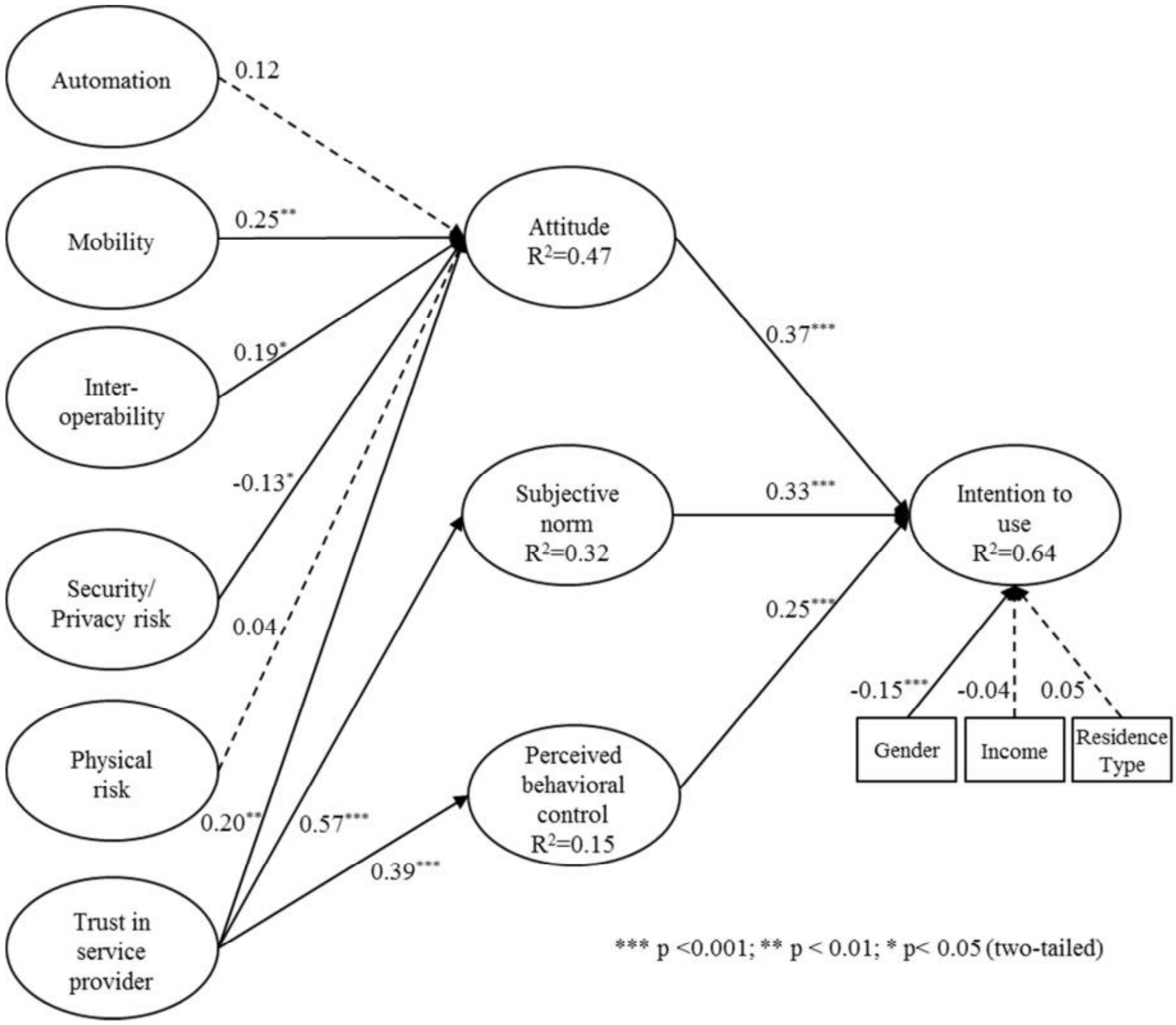

Figure 3 PLS results