Factors driving the adoption of smart home technology: An empirical assessment

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Published in:
Telematics and Informatics

DOI:
10.1016/j.tele.2019.101283

Published: 01/01/2019

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Abstract

Smart home technology, an application of Internet of Things (IoT), provides households with e.g., comfort, control and convenience. The technology has been around for sometimes, but its prevalence is not yet widespread, and thus the potentials have largely been underestimated. The purpose of this paper is to develop a comprehensive model that can explain a large percentage of variance in the intention to use smart home technology. To do so, this paper, based on technology acceptance model, diffusion of innovation theory and consumer perceived innovativeness, proposes an integrated model and validates it through Structural Equation Modelling on data collected from 156 respondents. The results reveal that compatibility, perceived usefulness and perceived ease of use are important determinants affecting the adoption of smart home technology. Moreover, trialability while show no direct effect on the intention to use, its affect is realized indirectly via constructs of PU and PEoU. The SEM results also show that the perceived cost negatively impacts the intention to use. This paper is one of the first empirical attempt that includes consumer perceived innovativeness in the model. This paper contributes to the literature of IoT, in particular to smart home technology research. Some theoretical and practical implications are discussed.

Keywords: Internet of Things, Perceived consumer innovativeness, Perceived cost, Smart home technology

1. Introduction:

Along with the rapid development of Internet from Web 1.0 to Web 4.0, the nature of Internet use over the past decades has become more complex (Boer et al., 2019). There are now more than four billion people around the world using Internet for various purposes, such as communications, social media networking, Web browsing, e-commerce, and online games (We are Social, 2018). Internet users expands even further and it comes as no surprise that the use of Internet, specifically with the emergence of Web 4.0 (Noh, 2015), will take on new forms and be used in more innovative ways. Internet of Things (IoT) with its unique characteristics [ubiquity, identity and connection] is one particular phenomenon that has particularly gained attention along with the rapid growth of Internet users (Evans, 2011; Perera et al., 2014). Although, there is no generally accepted definition of Internet of Things (IoT), it can be defined as an umbrella term for the internetworking of physical objects and devices, e.g., IoT-based smart homes (Mocrii et al., 2018), connected cars and autonomous driving (Athanasopoulou et al., 2019; Krasniqi and Hajrizi, 2016) and ubiquitous home control (Piyare, 2013). The IoT provides several potential benefits and enables another way of utilizing the technology which is highly dependent on sensor technology, i.e., *smart home technology*. Smart home technology as an application of IoT, is the integration of technology and services through home networking for controlling network-connected home systems and for a better quality of living (Robles and Kim, 2010). In other words, smart home technology is a contemporary application of ubiquitous computing that incorporates intelligence and automation into home environment for comfort, control, security, safety, healthcare, and energy conservation (Alam et al., 2012). Recently, Marikyan et al. (2019) define a smart home as a residence equipped with smart technologies which are aiming at providing tailored services for users. Smart home technology consists of hardware, sensors and switches and allows to design and develop new (smart) home appliances, digital devices and services to be used by households. Smart home appliances, products and services can be programmed to do almost anything; for instance, to notify the resident when the main gate is left open or when room temperature is high or low, to provide some degree of security for physically challenged people or to alert elderly people to take medicine.

Smart home technology for health and social care supports has extensively been studied (e.g., Liu et al., 2016; Martin et al., 2008), but far less attention has been paid to acceptance and adoption of smart home technology from household's perspective. In the scant literature, for example, in an attempt to identify factors influencing acceptance and (intended) usage of IoT, Boer et al. (2019) argue that several Internet skills (e.g., information navigation) associated with the operating the Internet-of-Things directly impact the use of IoT technology. Similarly, Kowalski et al. (2019) find that household members with high technical skills are more willing to adopt smart home services and products, mainly due to its administrative functions. This means inhabitants with high technical skills or skills associated with the operating objects connected to the Internet get empowered and can control the home environment (Kowalski et al., 2019). Moreover, Bradfield and Allen (2019) argue that current methodologies used for managing home energy consumption are inefficient and households need to adopt smart home technology if they want to improve their home management capabilities. In the same vein, Wang et al. (2018) evaluate both the positive factors and the risk factors associated with the use of smart home devices and argue that household members need to pay more attention to the potential benefits of the technology, and in particular the authors find performance expectancy and compatibility influence household's intentions to adopt smart home technology.

Despite the overall contributions of the above discussed studies, there is still a gap in the literature regarding a comprehensive model that explains, from users' perspective, a large percentage of variance in the intention to use smart home technology. Also, as the smart home technology is relatively new to users and its acceptance and pervasive use are still under research, it is equally important to understand how innovative this concept is to consumers. Against this backdrop, the overall theoretical objective of this paper is to develop and validate a comprehensive model using the key elements of the most widely used and validated acceptance and adoption theories such as Technology Acceptance Model (TAM: Davis, 1989), Innovation Diffusion Theory (IDT: Rogers, 2003) and perceived cost from Unified Technology of Acceptance and Use of Technology II (UTAUT2) developed by Venkatesh et al. (2012) which is a recent adaptation of the most widely used technology acceptance model. In addition to these mainstream theoretical frameworks, Consumers Perceived Innovativeness (hereinafter CPI) a concept developed by Lowe and Alpert (2015) seems to fit very well with the context of this paper. Responding to Venkatesh et al. (2003, p. 426) who state that researchers must *pick and choose* constructs across the models as they are confronted with a choice among a multitude of models, the present approach has been chosen for three reasons.

Firstly, TAM not only is the most widely used model to explain the underlying factors of user acceptance of new technologies (Shin et al., 2018), but also its determinants are crucial for investigating the acceptance of new technology as a social rather than a technical issue (Yi et al., 2006). Secondly, IDT is the primary innovation theory that tries to explain technology adoption. Moore and Benbasat (1991) argue that TAM and IDT are; however, similar in some constructs for examining the adoption of a new technology. These two theoretical models complement each other and share the same view that the adoption of a particular technology is determined by its perceived attributes (Lee et al., 2011). In the same vein, Moore and Benbasat (1991) argue that relative advantage from IDT is similar to the perceived usefulness (hereinafter PU) and complexity also from IDT is an inverse factor of perceived ease of use (hereinafter PEoU) in TAM. Therefore, in this paper in addition to PU and PEOU, these two constructs will not be included in the model, instead other constructs from IDT will be used. Some researchers such as Yang et al. (2017), Wu and Wang (2005) and Chen et al. (2002) claim that the integration of these two theoretical frameworks could provide a better model to explain a large variance in the intention to use technology. The integrated of TAM and IDT model has been used by prior studies, for example, Oh and Yoon (2014) and Sigala et al. (2000) or recently by (Hubert et al., 2018) to study the acceptance and adoption drivers on smart home technology usage. Thirdly, Benbasat and Barki (2007) reviewed TAM literature and found that due to the dominance of this theory, acceptance studies often focus on TAM without considering other theories. This claim has further been supported by Lowe and Alpert (2015) by showing that prior studies in innovation often sought to understand diffusion of new products by examining individual consumer behaviour processes, but never examined *"how new is new" or "how innovative is an innovation"* (Lowe and Alpert, 2015, p. 1). Thus, in addition to TAM and IDT, this paper includes CPI in the model to understand better the antecedent of intention to use smart home technology. Consumer perceived innovativeness is a theory that tries to explain questions such as: how innovative a new product is to consumers? Why is it perceived to be innovative and does perceived innovativeness affect consumer intention to adopt new products? (Lowe and Alpert, 2015). Therefore, by combining the determinants from these theoretical frameworks, this paper develops an integrated model to investigate the antecedents of the intention to use smart home technology.

Considering the wide availability of smart home technology for different use purposes, such as (i) devices and applications for home automation and comfort, (ii) applications and devices for health monitoring, (iii) sensors for home security, the factors affecting the intention to use a particular smart home technology may be completely different to those factors influencing the intention to use another smart home technology. But, it should be mentioned that in this paper we do not focus on or define any specific type or application of smart home technology. The intention is to test and examine the research model from a general perspective. The central question guiding this research is: *what antecedent factors influence individual's intention to use smart home technology?* We aim to answer this question through an empirical investigation of survey data comprising a sample of 156 Finnish households.

The reminder of this paper is structured as follows. Section two provides the theoretical background, presents the research hypotheses and the conceptual model is introduced. Section three provides the research methodology, followed by discussion of the findings in. Section five presents the discussions and conclusion is presented in Section six.

2. Theoretical framework and hypotheses development

2.1. Technology Acceptance Model (TAM)

Individual acceptance or use of technology is one of the most studied topics in Information Systems research and most often TAM is the model commonly used to investigate the technology acceptance (see e.g., Kim and Shin, 2015; Nikou and Bouwman, 2014; Shin et al., 2018). This model is useful in the empirical investigation of user perceptions of new technologies and for explaining the adoption process. The main constructs in TAM are PU and PEoU. Perceived usefulness "explains the degree to which an individual believes that using a particular system would enhance his or her job performance" and PEoU "explains the degree to which an individual believes that using a particular system would be free of physical and mental effort" (Davis, 1986). According to Davis (1989), PEoU affects intention to use both directly and indirectly (through PU). Shin et al. (2018) investigate factors affecting adoption and diffusion of smart home technology using an extended TAM model and find that both PU and PEoU, in addition to compatibility, have significant positive effects on intention to use. Moreover, Park et al. (2018) study adoption of smart homes by extending the original TAM model to an integrated model and find that perceived: compatibility, connectedness, control, system reliability, and enjoyment have significant positive effects on users' intention, while perceived cost negatively effects the intention to use.

The perceived (potential) advantages of a new technology (e.g., smart home technology) can be illustrated through e.g., smart temperature. By adjusting the room temperature autonomously, this function enables households to monitor their energy consumption, thereby providing both the living convenience and energy saving. The sensors used in this service can locate the household's position at the house and adjusts the room temperature upon leaving (by lowering the temperature) and returning (by raising the temperature) autonomously, resulting in a high PU in terms of the TAM. However, the autonomous character of this service may reduce the relevance of PEoU in this context, but its importance becomes apparent as most of the IoT home appliances need initial setup and personalization (Van Deursen and Mossberger, 2018). In the context of smart home technology, TAM has proven to be successful in explaining the acceptance of the technology (Karahoca et al., 2018; Park et al., 2018). Based on the above discussions, the following hypotheses can be derived:

H1: *Perceived usefulness (PU) positively affects the intention to use smart home technology.*
H2: *Perceived ease of use (PEoU) positively affects the intention to use smart home technology.*
H2a*: PEoU positively affects PU of a smart home technology.*

2.2. Innovation Diffusion Theory (IDT)

According to Rogers (1983) an innovation is an idea, practice or object that has distinct features which can be perceived as new. Rogers defines that diffusion is a process by which an innovation is communicated through certain channels over time among the members of a social system (1983). According to this theory, the underlying attributes of an innovation influence the adoption of a particular innovation, such that the rate can be either increased or reduced depending how attributes are being perceived. Based on the IDT, five key attributes namely: relative advantages, compatibility, complexity, trialability and observability, impact the adoption of innovation. Relative advantage accounts for the ability of an innovation to enhance the users' state of wellbeing and that the use of a new technology is highly dependent on the comparable benefits derived from its use (Taylor and Todd, 1995). However, as mentioned earlier, relative advantage is similar to the PU in TAM model, thus will not be included in the model. Compatibility is the second attribute of IDT and refers to the degree to which an innovation is perceived as being consistent with the existing systems, values, past experiences and needs of potential adopters (Rogers, 1983). Al-Majali and Nik Mat (2011) define compatibility as the extent to which an innovation supersedes all other options in meeting the desires and needs of potential adopters. In other words, compatibility is the ability of the technology to fit within the lifestyle of potential adopters.

The third attribute of IDT is complexity and refers to the degree to which an innovation is perceived as being easy or difficult to understand and/or to use (Rogers, 1983). As mentioned earlier, complexity and PEoU are very similar (Moore and Benbasat, 1991), thus only PEoU will be included in the model. The fourth attribute of IDT is trialability and refers to the degree to which an innovation may be experimented with on a limited basis (Rogers, 1983). Trialability provides the potential adopter the opportunity to test an innovation (e.g., smart temperature) on a limited time scale prior to making the final decision to adopt or reject a new technology. Rogers (1983) argue that trial of innovation reassures the adopter and reduces risks and uncertainty associated with adopting the technology. Also, it has been found that the likelihood of adopting an innovative technology will be increased if users are given the opportunity to experiment with the technology prior to adoption (Lee et al., 2011). Finally, the fifth attribute of IDT is observability (observed effects), which is the degree to which the results of an innovation are visible to others (Rogers, 1983). Observability has proven to be significant predictor of technology adoption, specifically in the adoption of Smart TV (Bae and Chang, 2012) and smart home services (Shih, 2013).

In summary, as the three attributes of IDT (i.e., compatibility, trialability and observability) according to Chen et al. (2009), Lee et al. (2011), Moore and Benbasat (1991), Mun et al. (2006), Wu and Wang (2005) and Wu et al. (2007) may exert their influence on usage intention either directly or indirectly through the TAM constructs (PU and PEoU), in the proposed model, these constructs will be conceptualized as the independent variables, and the PU and PEoU will be conceptualized as mediating variables. Consequently, the following hypotheses can be derived:

H3. *Compatibility positively affects the intention to use smart home technology.*

H3a. *Compatibility positively affects the perceived usefulness of smart home technology.*

H3b. *Compatibility positively affects the perceived ease of use of smart home technology.*

H4. *Trialability positively affects the intention to use smart home technology.*

H4a. *Trialability positively affects the perceived usefulness of smart home technology.*

H4b. *Trialability positively affects the perceived ease of use of smart home technology.*

H5. *Observability positively affects the intention to use smart home technology.*

H5a. *Observability positively affects the perceived usefulness of smart home technology.*

H5b. *Observability positively affects the perceived ease of use of smart home technology.*

2.3. Consumer Perceived Innovativeness (CPI)

Consumer perceived innovativeness refers to the perception of consumers towards certain products and how it affects their intention to use the technology (Hong et al., 2017). Other authors such as Aldás-Manzano et al. (2009) and Hirunyawipada and Paswan (2006) define consumer innovativeness as the tendency to buy new products more often and quickly than others. Lowe and Alpert (2015, p. 4) posit that CPI is the perceived degree of newness and improvement over existing alternatives. Lu et al. (2005, p.251) argue that individuals with higher personal innovativeness are expected to develop more positive beliefs about the target technology. Some studies such as (Kim and Shin, 2015) and (Thakur and Srivastava, 2014) showed that perceived innovativeness influence users' behavioural intentions. Therefore, in the context of smart home technology, we expect individual with higher degree of perceived innovativeness will have a higher intention to adopt the technology. Hence, the following hypothesis can be derived:

H6: *Consumer perceived innovativeness positively affects the intention to use smart home technology.*

2.4. Perceived cost

Perceived cost has widely been used in prior studies to empirically investigate the impact of this variable on users' intentions to use technology and have consistently been reported that high perceived cost has a direct, but negative effect on users' behavioural intentions to use technology (e.g., Shin, 2010; Shin and Kim, 2015; Wu and Wang, 2005). In the context of smart home technology, it is important to know "if users think smart home technology is affordable or expensive" and "if they are willing to pay the prices asked for home networked-connected appliances and devices". In this paper, it is assumed that users' intentions are largely determined by their perceptions of cost of *the technology. If users perceive the cost of smart home technology as expensive, they feel more restricted to adopt and use it. In other words, the higher the cost of smart home technology is, the lesser is the likelihood of its use. In line with these discussions, perceived cost of smart home technology is included in the research model, hence:*

H7: *Perceived cost will have a negative effect on intention to use smart home technology.*

2.5. Intention to use

The core theoretical focus of this paper is to identify the determinants of the intention to use smart home technology. In the context of IoT, Bai and Gao (2014) used an integrated model to find factors influencing individuals' willingness to use IoT technology and found that PU is the most notable and powerful predictor of individuals' intention to use the technology. In this paper, intention to use as a construct is conceptualized as a dependent variable. In our model, the two key constructs of TAM: PU and PEoU are assumed to affect the intention, according to Davis (1989) PU and PEoU are the main determinants of technology acceptance. Some authors such as Hubert et al. (2017) in the context of acceptance of smartphone-based mobile shopping and Boer et al. (2019) in the context of IoT acceptance by households show that PU is an important determinants of IT acceptance and can explain a large proportion of variance in the intention to use an innovation.

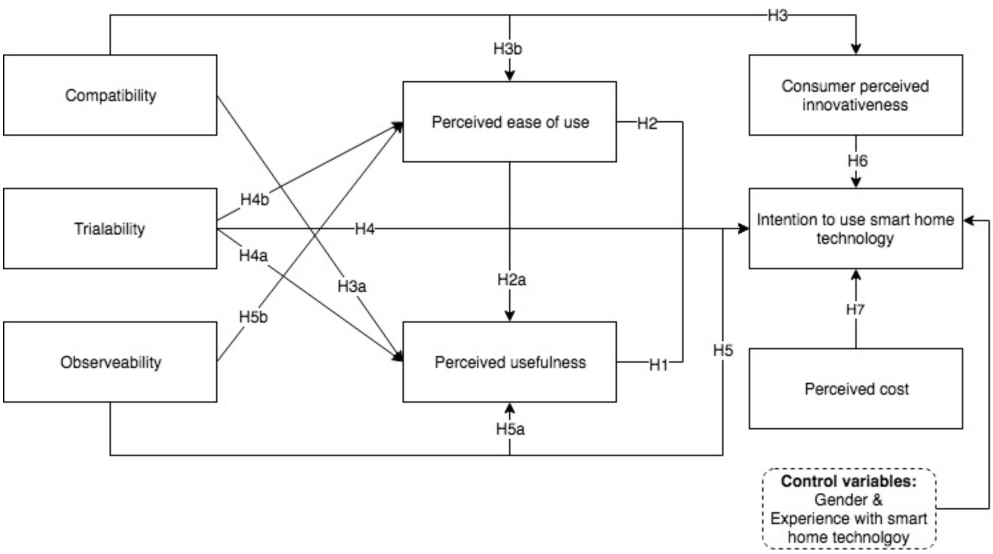

Figure 1: Research model.

Moreover, PEoU which is the individual's assessment of the effort associated with the usability and the learning of a technology, not only influence the intention both directly and indirectly (through PU), but also influence the perception of their usefulness (Chen et al., 2009; Davis, 1989; Davis et al., 1989; Lee, 2009). Figure 1 shows the proposed research model and depicts the hypothesized relationships between the constructs within the TAM, IDT and CPI. In addition to the main constructs, previous experience with smart home technology and the gender of the respondents will be used as control variables to investigate if these variables impact the path relationships in the model.

3. Methodology

3.1. Data collection procedures

We developed a web-based survey to collect data from households in Finland. Before distributing the survey, it was pretested by 22 households with different demographic background, e.g., familiarity and previous experience with the smart home technology and the gender. The main intention was to collect feedback and comments from potential users to improve the clarity of the questions and avoiding the ambiguous expressions. Next, the modified version of the survey was distributed to individuals who were randomly recruited through the author's contacts over the course of six weeks. The link to the survey was sent to 220 potential respondents and 189 responses were received. After removing the incomplete responses (e.g., missing data or unengaged respondents), 156 responses met the inclusion criteria and were included in the final data analysis. Hair et al. (2011) recommended that the sample size should be ten times the largest number of structural paths directed at a particular latent construct in the structural model, thus in terms of sample size requirement, we conclude that the collected responses exceeded the requirement of sample size.

With respect to incentives to encourage the participants, we did not provide any incentives. However, respondents were assured that their personal information would be treated anonymously and will be only used at an aggregate level. This approach enabled us to control for potential common method bias, CMB could be an issue with self-report studies (Chang et al., 2010). Respondents were promised to receive a personalized report and an in-depth analysis of the research findings; this approach helped to reduce nonresponse bias (Sax et al., 2003). A short video[1] about the smart home technology was provided through a YouTube link in order to familiarize the potential respondents with the concept of smart home technology and IoT in general, the smart home environment, and the existing products and home appliances in the market. It is also important to mention that respondents were completely free to choose to watch the video, but were strongly recommended to watch of the video. This approach has proved to be an effective method helping respondents to form a general understanding about the phenomenon being under investigation (Luor et al., 2015). Furthermore, respondents were asked to indicate if they have previously used or experienced with the smart home technology.

[1] https://www.youtube.com/watch?v=HL0V_DmKJw4

3.2. Measurement

Items for measuring the seven constructs in the model were drawn from previously validated studies (see Appendix A). If needed, minor modifications were made on the items to match the context of this study. All variables included in the model have been assessed from a general perspective of the smart home technology and thus no questions regarding any particular smart home technology or smart home products and services were asked. Consumer perceived innovativeness (CPI) was measured through three items (Garcia and Calantone, 2002; Lowe and Alpert, 2015). The perceived cost was measure by 4 items from (Shin and Kim, 2015; Venkatesh et al., 2012). The intention to use smart home technology were measured with 3 items (Bagozzi and Burnkrant, 1979; Davis et al., 1989; Davis, 1986). For measuring the PU and PEoU, each with four items, we used an adapted version of the original instrument from (Davis, 1986). Three constructs of IDT, i.e., compatibility, trialability and observability, were measured with 4, 3, and 3 items, respectively, all derived from Rogers (1983). The items were answered using a 7-point Likert scale ranging from "*Strongly disagree*" (1) to "*Strongly agree*" (7).

4. Data analysis and results

In this section, the descriptive analysis, the measurement and the structural model results are illustrated and discussed. To test the research hypotheses shown in the conceptual model, Figure 1, we applied Structural Equation Modelling (SEM) using SmartPLS version 3.0.

4.1. Descriptive analysis

In average, it took 17 minutes to complete the survey. Respondents were divided into two groups as early or late respondents. The groups were compared on their responses to the Likert scale questions using *t*-tests. The test result shows no differences between the early and the late responses. The average age of the respondents was 29.5 years old and 109 (～70%) of them were males and 45 (～30%) were females, two did not reveal their gender. Interestingly, more than half of the participants have reported that they have watched the video (the majority were those who did not use smart home technology before their participation to this research). Around one third (N = 52) reported that they have previously used or experienced the smart home technology prior to this research.

4.2. Measurement model

A two-step approach was followed to assess the measurement model and the structural model (Anderson and Gerbing, 1988). For examining the internal consistency and discriminant validity of the measures, a confirmatory factor analysis (CFA) was run for all the constructs depicted in Figure 1, see Table 1 for the correlations between the variables.

Table 1. Correlation matrix

	COMP	CPI	PCost	INT	OBS	PEoU	PU	TRI
Compatibility	-	.490	.064	.809	.166	.444	.706	.704
Consumer perceived innovativeness		-	.151	.578	.043	.588	.433	.455
Perceived cost			-	.089	.325	.066	.239	.120
Intention to use				-	.251	.547	.718	.629
Observability					-	.067	.228	.243
Perceived ease of use						-	.494	.527
Perceived usefulness							-	.735
Trialability								-

The measurement model results showed that all the items were loaded into their respective constructs, expect for 2 items from perceived cost which were removed from further analysis. Moreover, as we used SmartPLS for the analysis, it should be mentioned that PLS-SEM lacks a globally accepted method for assessing the overall model fit. Instead, as recommended by Hair et al. (2014), we relied only on the path coefficients and their significance. However, Hooper et al. (2008) and Hu and Bentler (1998) recommended to use the value of standardized root mean square residual (SRMR) to show the assessment of model fit. Values for SRMR range from 0 to 1, and values lower than .08 are considered a good fit (Hooper et al., 2008; Hu and Bentler, 1998). The SRMR value in our analysis is .074. The internal consistency was examined through the Cronbach's alpha, composite reliability and the average variance extracted (AVE).

Table 2. Measurement and internal validity

Construct	Item	Mean	Std. Dev.	Factor loadings	α	CR*	AVE*
Compatibility	COMP1	4.833	1.44	.926	.937	.955	.842
	COMP2	4.603	1.551	.941			
	COMP3	4.865	1.442	.881			
	COMP4	4.833	1.44	.923			
Trialability	TRI1	5.609	1.309	.906	.847	.841	.726
	TRI3	5.897	1.183	.679			
Observability	OBS1	5.026	1.502	.698	.701	.806	.681
	OBS2	5.006	1.607	.939			
Perceived usefulness	PU1	5.135	1.166	.826	.855	.902	.698
	PU2	5.282	1.192	.874			
	PU3	5.282	1.176	.881			
	PU4	4.282	1.488	.756			
Perceived ease of use	PEoU1	4.474	1.283	.827	.869	.909	.714
	PEoU2	5.359	1.315	.848			
	PEoU3	4.577	1.378	.854			
	PEoU4	4.763	1.287	.85			
Consumer perceived innovativeness	CPI1	5.647	1.176	.747	.800	.909	.833
	CPI2	3.923	1.862	.906			
	CPI3	4.263	1.622	.781			
Perceived cost	Cost1	5.89	1.02	.895	.7.2	.859	.753
	Cost2	5.28	1.44	.893			
Intention to use	INT1	5.205	1.539	.935	.854	.912	.777
	INT2	5.449	1.411	.887			
	INT3	3.583	1.761	.818			

Note: CR = composite reliability; AVE = average variance extracted.

Cronbach's alpha (α) values were all above the threshold of .60 (ranged from .701 to .937. The AVE values ranged from .681 to .842, CR values ranged from .806 to .955, all well above the recommended minimum of .50 and .70, respectively (Bagozzi and Yi, 1988), see Table 2. The standardized item loadings (22 items in total) for each construct are shown in Table 2, all exceeding the recommended value of .70. Due to low factor loading, one item from the observability was removed from the analysis.

Discriminant validity was examined to assess if each construct's AVE square root was greater than its highest correlation with any other construct, and the results showed no discriminant validity issue in the data (see Table 3).

Table 3. Discriminant validity (diagonal values show AVE square root)

	COMP	CPI	POCST	INT	OBS	PEoU	PU	TRI
Compatibility	**.843**							
Consumer perceived innovativeness	.425	**.831**						
Perceived cost	.049	.108	**.867**					
Intention to use	.728	.480	.071	**.881**				
Observability	.144	.037	.241	.206	**.825**			
Perceived ease of use	.407	.493	.049	.482	.054	**.845**		
Perceived usefulness	.635	.360	.193	.619	.185	.435	**.835**	
Trialability	.632	.370	.089	.542	.199	.465	.632	**.874**

The common method bias (CMB) was assessed according to Kock (2015) recommendation which is based on variance inflation factor (VIF). Kock (2015) argued that if the VIF value is greater than 3.3, then it could be an indication of CMD in the data. In this paper, the collinearity test was computed and all the VIFs at the factor level were equal to or lower than 3.3, thus we concluded that the model can be considered free of CMB (Kock, 2015, p. 7). The highest VIF value was 2.68.

4.3. Structural model and hypotheses testing

The SEM results from testing the validity of a causal structure of the conceptual model show that the structural model has satisfactory levels of fit index (SRMR value is .052) and NFI (.815). The standardized path coefficients presented in Figure 2 and Table 4 show a number of significant direct and indirect effects among constructs of TAM (PU and PEoU), IDT (compatibility, trialability and observability), consumer perceived innovativeness (CPI) and intention to use the smart home technology. Moreover, perceived cost, although significantly affect intention to use, its effect as expected is negative. Except of four hypotheses, all the hypotheses were supported by the model, in other words, the proposed research conceptual model provided an adequate explanation for the intention to use smart technology. Figure 2 shows that the intention to use smart home technology is explained by a variance of 62%, indicating that the predictors (PU, PEoU and CPI) explained a large amount of variation in this construct. Perceived usefulness and perceived ease of use are explained by a variance of 51% and 24%, respectively, see Figure 2.

Table 4. Significant direct, indirect, and total effects of determinants of intention to use smart home technology

Path relationship	Direct effects β	Indirect effects β	Total effects β	Hypothesis validation
H1: PU — Intention to use	.21	-	.21	**Supported**
H2: PEoU — Intention to use	.13	.026	.16	**Supported**
H2a: PEoU — PU	.13	-	.13	**Supported**
H3: Compatibility — Intention to use	.49	.11	.60	**Supported**
H3a: Compatibility — PU	.37	.035	.39	**Supported**
H3b: Compatibility — PEoU	.19	-	.19	**Supported**
H4: Trialability — Intention to use	-	.12	.10	*Rejected*
H4a: Trialability — PU	.33	.046	.37	**Supported**
H4b: Trialability — PEoU	.35	-	.35	**Supported**
H5: Observability — Intention to use	-	.006	.11	*Rejected*
H5a: Observability — PU	-	-.006	.06	*Rejected*
H5b: Observability — PEoU	-	-	.-.04	*Rejected*
H6: CPI — Intention to use	.15	-	.15	**Supported**
H7: Perceived cost — Intention to use	-.13	-	-.13	**Supported**

Note: Effects are significant at $p < .001$, except for Compatibility to PEoU ($p < .05$)

The structural model results reveal that the path between PU and intention to use is significant (β = .21, t = 2.555, p = .001), providing theoretical support to accept *H1* in the model. Moreover, the SEM results reveal that PEoU not only has a positive direct effect on the intention to use (β = .13, t = 2.225, p = .001), but also has an indirect (via PU) effect on the intention as it has a positive effect on PU (β = .13, t = 2.064, p = .001), thus *H2* and *H2a* are supported by the model, respectively.

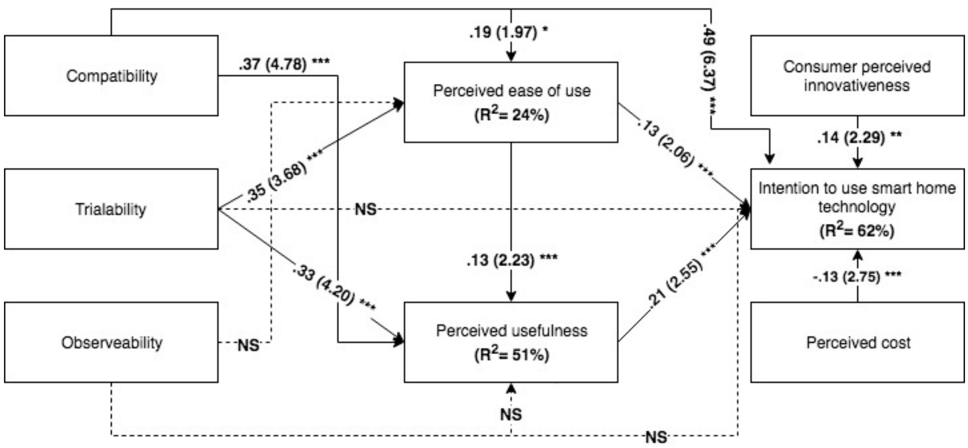

Figure 2: Structural model result

Note: *p < 0.05; **p < 0.01; ***p < 0.001; The dotted lines are non-significant

Compatibility, not only has a direct significant effect on the intention to use (β = .49, t = 6.369, p = .001), but also has a significant effect on both PU (β = .37, t = 4.785, p = .001) and PEoU (β = .19, t = 1.972, p = .05), therefore *H3, H3a* and *H3b* are supported by the model. This means that compatibility has also an indirect effect on the intention, but the effect goes only via the PU (β = .08, t = 2.075, p = .05). According to the SEM results, compatibility has the strongest direct effect on the intention to use smart home technology. The SEM results show that trialability has no significant direct effect on intention to use; therefore, rejecting *H4*. But it has a significant effect on both the PU (β = .33, t = 4.197, p = .001) and PEoU (β = .35, t = 3.679, p = .001); thus, both *H4a* and *H4b* are supported by the model. This observation indicates that there is an indirect effect of trialability (only via PU) to intention to use (β = .07, t = 2.055, p = .05). Surprisingly, the SEM results show that observability, a construct from IDT, has no direct effect on the intention to use, PU and PEoU, therefore *H5, H5a,* and *H5b* are all rejected by the model.

Moreover, consumer perceived innovativeness (CPI) has a positive direct effect on the intention to use (β = .14, t = 2.291, p = .01), thus *H6* is supported by the model. It should be noted that, while trialability and observability, both constructs from IDT had no direct effect on the intention to use smart home technology, other determinants in the model, i.e., PU and PEoU both from the TAM model, in addition to compatibility and CPI have direct and positive relationships with the intention to use smart home technology. Finally, as we expected, perceived cost has a significant effect on the intention to use, and the SEM results show that the effect of perceived cost to intention to use smart home technology is negative (β = 0.13, t = 2.75, p < 0.001), thus *H7* is supported by the model. This indicates that the behavioural intentions might become more negative when individuals find the perceived cost of smart home technology is high.

4.4 Multigroup Analysis (MGA)

The gender of the respondents and their previous experience with the smart home technology were used as control variables in the multigroup analysis (MGA). The objective was to examine if any differences between females and males and also between the experienced and non-experienced respondents regarding their perceptions toward smart home technology can be found. The MGA results revealed some interesting differences between the groups in the following path relationships. For instance, the MGA results show that the path between trialability and PU is not significant for the experienced respondents, but it is significant for the non-experienced respondents (β = .51, t = 3.721, p < .001). This indicates that the degree to which how easily the potential users can explore and examine an innovation facilitates the adoption of an innovation. In other words, for the non-experienced respondents, the trialability is a decisive key factor and having the opportunity to experiment with and test the smart home technology prior to its adoption will help them to recognize its usefulness. Moreover, another group difference can be observed in the path between the trialability and PEoU. Such that this path is significant for the experienced respondents (β = .41, t = 3.627, p < .001), but it is not for the non-experienced ones. A plausible explanation could be: if the users are given the opportunity to examine the technology prior to adoption, then they will have a clear picture about the degree to which using a particular system would be free of physical and mental efforts. Moreover, the MGA results show that the path between consumer perceived innovativeness to the intention to use is significant (β = .10, t = 1.99, $p < .005$) for those who indicated that they have not previously used the smart home technology. This path, however, is not significant for the other group. Perhaps for those who have not been exposed to or have not examined/tested the technology before, it would be difficult to assess how innovative is the technology or to assess the perceived degree of its newness over the existing alternatives.

With regard to gender, the multigroup analysis results show that there is a gender difference in the path between compatibility to PU, such that the effect is significant for the females (β = .37, t = 4.56, $p < .01$), but it is not significant for the males. In other words, females need to know whether an innovation (e.g., smart home technology) will be compatible with their lifestyle or not and then its usefulness could be realized. This finding is in line with Shin et al. (2018) who also found a significant gender difference. The MGA results also reveal that for female the path between perceived cost to intention to use is significant (β = .30, t = 2.436, $p < .01$), but for males this path is not significant. Again, this suggests that females are more likely than males to consider the cost of, e.g., smart home technology before making the adoption decision.

5. Discussion

This paper investigates smart home technology, an application of Internet of Things (IoT), from the Finnish households' perspectives. The core theoretical objective of this paper is to develop a comprehensive conceptual model that can explain a large proportion of variance of the intention to use smart home technology. To do so, using Structural Equation Modelling (SEM), we propose and examine an integrated model comprising constructs from the technology acceptance model (TAM: Davis, 1989), diffusion of innovation (IDT: Rogers, 1983), perceived cost (Venkatesh et al., 2012), and consumer perceived innovativeness (CPI: Lowe and Alpert, 2015).

With regard to the acceptance model, i.e., TAM constructs, the results demonstrate that PEoU not only has a direct effect on the intention to use, but also it has an indirect effect through the PU on the intention to use. Furthermore, the SEM results show that PU has a direct effect on the intention to use smart home technology. This finding, while is in line with the literature (e.g., Kim et al., 2017; Shin et al., 2018; Yang et al., 2017), suggest that both TAM constructs, i.e., PU and PEoU are the key factors that influence the intention to use smart home technology. Moreover, the SEM results, against our expectation, show that observability, a construct from the IDT has no effect, neither directly on the intention to use nor an indirect effect through PU. The results show that trialability has no direct effect on the intention to use, this finding is also in line with the prior studies (e.g., Moore and Benbasat, 1991). However, the results show that trialability indirectly influence the intention to use, such that the effect is observed only through PU. Trialability, which means having the opportunity to experiment with an innovation prior to adoption, seems to be one of the key factors of the adoption decision. The third construct of IDT, i.e., compatibility, has direct effect on the intention to use, PU and PEoU. The strong effect of compatibility on the intention to use and PU is similar to the findings of prior studies (e.g., Hubert et al., 2018; Lee et al., 2011; Shin et al., 2018; Wang et al., 2018).

The SEM results also show that perceived cost has a significant negative impact on the intention to use smart home technology. Furthermore, by including the consumer perceived innovativeness in the model, the results show interesting observations. The SEM results show that CPI has a direct and positive effect on the intention to use smart home technology, and yet this effect is different among experienced and non-experienced respondents. This finding addresses the concern raised by Lowe and Alpert (2015) who argue that literature on acceptance of technology is dominated by TAM model and most of prior studies in innovation often sought to understand diffusion of new products by examining individual consumer behaviour processes, but never examined *"how new is new" or "how innovative is an innovation"* (Lowe and Alpert, 2015, p. 1).

6. Conclusion

This paper contributes to the literature of smart technology acceptance by developing a comprehensive conceptual model of consumer intention to use smart home technology, starting with introducing of an integrated model comprising of perceived cost, consumer perceived innovativeness (CPI) in addition to the widely used acceptance and adoption theoretical models, i.e., TAM, IDT. This paper is the first to present how CPI contributes to the acceptance of smart home technology. With this approach, this paper contributes to literature by providing a better understanding of the individual perception towards smart home technology and yet the findings provide evidence on how demographic variables, i.e., gender and prior experience of smart home technology moderate the path relationships. In particular, evidence supports the idea that intention to use smart home technology is largely explained by CPI and perceived cost, in addition to the constructs of technology acceptance model and diffusion of innovation theory. The results of this research show that compatibility, PU and PEoU in addition to CPI have significant positive effects on the intention to use, and perceived cost has a significant negative impact on the intention to use. These findings are to a large degree consistent with the prior studies in literature (e.g., de Sena Abrahão, et al., 2016; Hubert et al., 2019; Mocrii et al., 2018; Shin et al., 2018; Wang et al., 2018). Moreover, the effect of compatibility to PU is positively significant for females, but not for the males, while path between trialability and PU is only significant for the non-experienced respondents.

Concerning the research question: what antecedent factors influence individual's intention to use smart home technology? — we can conclude that perceived usefulness and perceived ease of use are important for forming the individual's behavioural intention and their perception of IoT; in particular, smart home technology. From a more theoretical standpoint, this paper contributes to the literature by showing that two out of the three constructs of IDT, namely, compatibility and trialability, directly or indirectly contribute to adoption of smart home technology. The lack of significant direct links between observability, which is the degree to which the results of an innovation are visible to others, to PU, PEoU and intention to use could indicate the unawareness of the respondents about the potential benefits of the smart home technology. Plausibly, the absence of clear assessment about the advantages that the technology can offer forms a pragmatic mindset hindering the willingness to adopt, and also limiting the realization of how easy it is to use it or how useful the smart home technology can be.

6.1. Implications

This paper provides several useful insights and new knowledge for the practitioners and the providers of smart home products and services. For instances, the insights regarding the negative impact of perceived cost to intention to use smart home technology has a direct implication to vendors and service providers and how they define their pricing strategy on smart home technology. Moreover, to increase the adoption rates, providers should focus on developing services and products that enable households to easily operate services with the minimal mental and physical efforts and also making them compatible with the existing home appliances and services with the reasonable and affordable price. Moreover, service providers should be aware of and pay close attention to the concept of mobility, such that they design smart home products and services which enable users to have access to the services while are on the move and have the possibility to control and monitor their home environments, through e.g., mobile applications.

Smart home technology is gaining massive popularity and its significance is growing rapidly, our findings show that the perceived consumer innovativeness has a direct effect and at the same time perceived cost has a direct negative effect on the intention to use smart home technology, something that providers should pay a close attention. Moreover, the service providers need to know how to define and approach the potential users. Technology suppliers, service providers and policymakers are advised to take a broad view and be sensitive to individual's concerns about the usefulness and the compatibility of the technology with the existing products and services. Another practical implication of the findings is that emphasis should be placed on females' needs and their perceptions toward the smart home technology, specifically with regard to cost of the technology. The results show that their perceptions toward this innovation is greatly affected by its usefulness, price and to what degree an innovation (e.g., smart home technology) will be compatible with their lifestyle.

6.2. Limitations and future research

This paper has several limitations that need to be addressed, the first limitation concerns generalizability of the findings. As our study was conducted in Finland, a country in the Northern Europe with high penetration of advanced technology users, the findings may not be applicable to the countries that are less technologically advanced. Moreover, as our sample's prior knowledge and experience with the smart home technology is somewhat skewed, 52 out of 155 respondents, the findings may not be applicable to those who are heavy users of the smart home technology. Also, we have investigated smart home technology in general and in the context of Finnish households, future research can build on our study by testing the proposed model in different countries focusing on; for example, one specific smart home technology service.

The sample size for the multigroup analysis might be an issue in this research, considering the fact that there is no consensus in the literature regarding the appropriate sample size for SEM. Some researchers, such as (Bentler and Chou, 1987) argue that the sample size should be considered based on the number of observed variables and the author suggested a ratio as low as five cases per variable. However, (Nunnally, 1967) argue that for each variable in the research at least 10 cases are needed for SEM analysis and with regard to multigroup analysis, the rule of thumb is 100 observations per group (Kline, 2005).

Finally, prior studies have shown that hedonic motivation plays an important role in determining technology acceptance and use (Venkatesh et al., 2016). Hedonic motivation, a construct often labelled as a perceived enjoyment in Information Systems research, can be added to the model in future studies to determine its potential effect on the smart home technology acceptance. Moreover, we suggest to include other constructs, such as privacy and security in future studies. Because, privacy and security issues might hinder the proliferation of the use of the smart home technology. Lee et al.

(2014, p. 72) argue that while smart home technology is becoming increasingly popular, the security challenges and threats to the existing solutions for smart homes are less studied or Yang et al. (2014) argue that security and privacy risk negatively affect users' attitude toward using the smart home technology.

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Appendix A:

Constructs		Items
Compatibility	COMP1	I feel that the Smart Home appliances fits my lifestyle.
	COMP2	I feel that the Smart Home appliances are compatible with my day-to-day needs.
	COMP3	I think that the Smart Home appliances will fit well into my home.
	COMP4	I think that the Smart Home products and applications are useful for the tasks I do at home.
Trialability	TRI1	Being able to try out and experiment with the Smart Home appliances before purchasing it is very important to me.
	TRI2	It is important to ask questions about Smart Home appliances before buying and installing them.
	TRI3	I do not need to see how the Smart Home appliances work before I buy and install them.
Observability	OBS1	It is important for me to see the benefits of others using Smart Home appliances.
	OBS2	Observing other Smart Home users before installing and using Smart Home appliances is necessary.
	OBS3	Seeing others use Smart Home technologies would have an effect on me.
Perceived usefulness	PU1	I feel that the Smart Home would enable me to accomplish tasks more quickly.
	PU2	I feel that installing and using the Smart Home would make things easier to do.
	PU3	I feel that I would find Smart Homes useful for doing various tasks at home.
	PU4	I feel that using Smart Homes would increase my productivity at home
Perceived ease of use	PEoU1	I feel that the Smart Home appliances are easy to install and use.
	PEoU2	I feel that it is easy for me to learn to use the Smart Home appliances.
	PEoU3	I feel that it is easy to get the Smart Home appliances and devices to do what I want them to do.
	PEoU4	I would find the Smart Home to be flexible to interact with.
Perceived cost	Cost1	I fear that the cost of Smart Home appliances is going to be way over my budget.
	Cost2	I consider cost carefully before I install Smart Home technologies.
	Cost3	Economic uncertainty affects my purchase decisions.
	Cost4	Given the current economic situation, I would carefully look at the cost of Smart Home technologies.
Consumer perceived innovativeness	CPI1	Smart Home products and applications are innovative
	CPI2	Smart Home products and applications are totally new to me.
	CPI3	When I first heard about Smart Homes products and applications, my impression was "Wow!"
Intention to use	INT1	I intend to use Smart Home technology in the future.
	INT2	Given that there are more and more Smart Home products and services in the market, I predict that I would intend to use them.
	INT3	I plan to install Smart Home technology in my house in the near future.