Understanding the Adoption of Smart Wearable Devices to Assist Healthcare in China

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Abstract. With the development and advancement of information communication technology, smart wearable devices are playing a more and more important role in peoples' daily lives. This study aims to investigate the adoption of smart wearable devices to assist healthcare in China. Based on the previous technology diffusion theories (e.g., TAM, IDT), a research model with ten research hypotheses was proposed in this research. The research model was empirically tested with a sample of 180 users of smart wearable devices in China. The results indicated that seven of the ten research hypotheses were significantly supported. The most significant determinant for users' attitude towards smart wearable devices was trust. However, personal characteristics did not have a significant positive impact on both users' attitude and behavior intention to use smart wearable devices.

Keywords: Adoption · TAM · Trust · Smart wearable devices

1 Introduction

Building smart cities has been a popular topic in China recently. Smart cities can be explained as those cities that utilize information and communication technologies with the aim to increase the life quality of their inhabitants while providing sustainable development [4]. Consequently, the cities are able to become more intelligent in their management of resources.

With peoples' increasing demand for high quality of life, healthcare has been an essential issue in peoples' daily lives. For example, people who go to large hospitals usually need to wait for a long time to see a doctor and pay high medical costs. Having treatments in the medical community is an alternative for patients. It can save patients' waiting time. Furthermore, primary healthcare services have low operating costs and can save a lot of expenses for patients in taking treatments and buying drugs.

With the development and advancement of information communication technology, smart wearable devices (SWD) with variety of sensors are playing a more and more important role in peoples' daily lives. Smart wearable technologies can

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sometimes enable people to live in their own homes and monitor their own wellbeing rather than being hospitalized or institutionalized [28]. Smart wearable technologies can help patients manage their wellbeing by examining the relevant indexes. Taking the advantage of SWD, the medical community is able to make it more convenient for people to get medical treatments, optimize the allocation of resources and form a rational advanced medical system.

User preferences for the use of SWD in their daily lives need to be studied before actual use of these devices becomes a common practice. To our knowledge, there is a lack of literature that explores the perceptions of peoples' attitude towards SWD to assist healthcare in China. The objective of this paper is to study the adoption of SWD to assist healthcare in China. The major constructs from technology diffusion theories (e.g., TAM [7] and IDT [32]) are chosen to form a research model to examine the potential factors that affect users' adoption of SWD in China.

The remainder of this paper is organized as follows: the literature review is provided in Sect. 2. Section 3 proposes the research model and research hypotheses. This is followed by the illustration of the research method and the research findings in Sect. 4. The discussion of the findings is presented in Sect. 5. In Sect. 6, we conclude this research and point out future research directions.

2 Literature Review

2.1 Smart Wearable Devices

Wearable technology and wearable devices are phrases that describe electronics and computers that are integrated into clothing and other accessories that can be worn comfortably on the body [36]. While these devices carry out many of the same tasks as handheld technologies such as mobile phones and laptop computers, they can actually surpass them in performance due to sensory and scanning features such as biofeedback and tracking of physiological function. Examples of wearable devices include watches, glasses, contact lenses, e-textiles and smart fabrics, headbands, beanies and caps, jewelry such as rings, bracelets, and hearing aid-like devices that are designed to look like earrings [36]. The major providers of SWD in China include: Baidu, iGeak, SmartQ, BabyTree, Tenghai Shiyang, Qihoo360, Hoolai Games.

SWD have the potential to monitor and respond to both the patient and the patient's environment. For monitoring patients' wellbeing, an SWD may include a wide range of wearable or implantable devices, including sensors, actuators, smart fabrics, power supplies, wireless communication networks (WCNs), processing units, multimedia devices [6].

2.2 Technology Diffusion Theory

An important and long-standing research question in information systems research is how we can accurately explain user adoption of information systems [8]. Several models have been developed to test the users' attitude and intention to adopt new technologies or information systems. These models include the Technology

Acceptance Model (TAM) [7], Theory of Planned Behavior (TPB) [1], Innovation Diffusion Theory (IDT) [32], Unified Theory of Acceptance and Use of Technology (UTAUT) [29]. Among the different models that have been proposed, TAM, which is the extension of the Theory of Reasoned Action (TRA) [11], appears to be the most widely accepted model. TAM focus on the perceived usefulness (PU) and perceived ease of use (PEOU) of a system and has been tested in some domains of E-business and proved to be quite reliable to predict user acceptance of some new information technologies, such as electronic commerce [30], and online shopping [19].

However, TAM's limitations relative to extensibility and explanation power have been noted [5]. Many researchers have suggested that TAM needs to be extended with additional variables to provide a stronger model [12, 15, 24]. Some researchers have also indicated that the major constructs of TAM cannot fully reflect the specific influences of technological and usage-context factors that may alter users' acceptance [29]. Therefore, PU and PEOU may not fully explain people's intention to adopt mobile services. We believe that TAM has limitations when investigating users' adoption of mobile services, which is also confirmed by prior research work in [17, 37]. Moreover, although UTAUT unifies more factors and consolidates the functions of the technology acceptance model with the constructs of eight prominent models in IS adoption research, this increases the complexity, so that it is more complicated to test its applicability.

There are only few studies addressing the adoption of smart wearable devices. For example, Kim and Shin [22] developed an extended technology acceptance model to examine the adoption of smart watches in South Korea. The results indicated that affective quality and relative advantage of smart watches were found to be associated with perceived usefulness, while the sense of mobility and availability induced by smart watches led to a greater perceived ease of the technology's use. Furthermore, Gao et al. [18] examined the factors associated with consumers' intention to adopt wearable technology in healthcare.

To our knowledge, there is a lack of empirical studies which address the adoption of smart wearable devices to assist healthcare in China. This explorative study aims to begin to fill this knowledge gap. All the findings above motivate the development of a research model, which is described in next section.

3 Research Model and Hypotheses

3.1 Research Model

A research model that identifies important factors as significant antecedents of users' intention to use SWD was developed. The proposed acceptance model is an extension of TAM. In addition to the constructs from TAM, the model includes Trust, Perceived Risks, Personal Characteristics, Compatibility as other factors to study users' adoption of SWD. Table 1 summarizes the definition of the constructs in the research model (see Fig. 1).

Table 1. The definitions of the constructs

Construct	Definition	Reference
Perceived usefulness	The degree to which a person believes that using a particular system would enhance his or her task	[7]
Perceived ease of use	The extent to which a person believes that using a particular system would be free of effort	[7]
Compatibility	The extent to which a potential customer's value, self-demand, precious experiment are matching with a particular system	[32]
Attitude	The possibility of a user to accept a particular system	[7]
Behavior intention	The user's desire to accept a particular system	[7]
Personal characteristics	The extent to which user's gender, sex, age, education background and occupation that affect the acceptance to a particular system	[14]
Trust	The extent to which a person believes that using a particular system would be safe and high quality	[20]
Perceived risks	The risks to which a person believes that using a particular system	[10]

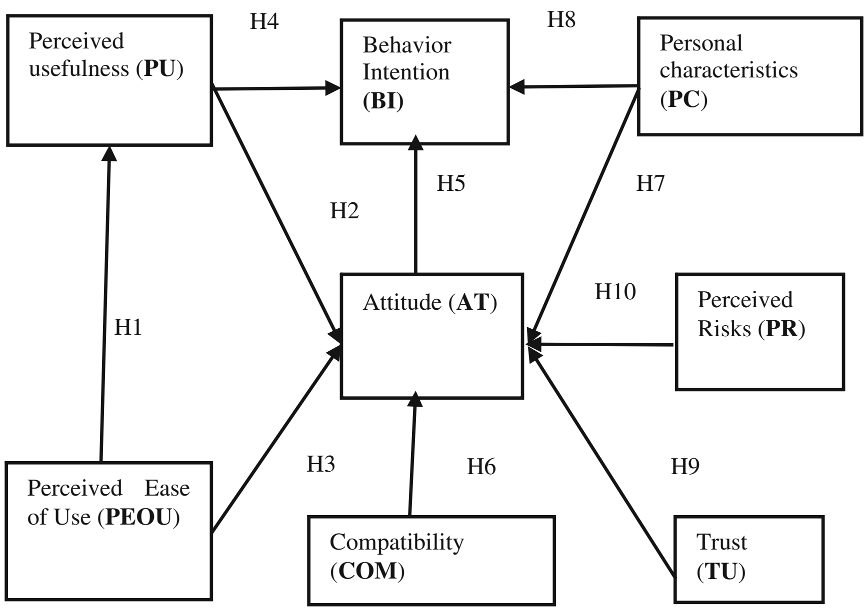

Fig. 1. Research model

3.2 Research Hypotheses

Previous studies have found the positive relationship between perceived ease of use and users' attitude in the IS context (e.g., [13]). In the original TAM model, Davis proposed that perceived ease of use (PEOU) affects perceived usefulness (PU). There are extensive empirical evidences that perceived ease of use positively influences perceived usefulness (e.g., [13, 25]). For example, Van der Heijden [33] found that this relationship holds true for website usage in an Internet environment. Furthermore, Perceived usefulness was found to have a strong effect on technology adoption (e.g., including adoption of WWW [21], and wireless internet [26]). The empirical findings in these studies demonstrated the importance of perceived usefulness on behavior intention (BI) to use the technologies. Rogers [32] indicated that innovation that are perceived by individuals as having greater relative advantage, compatibility, trialability, and observability, and less complexity will be adopted more rapidly than other innovation. To further understand users' attitude towards SWD, one factor from IDT was also included into our research model. Compatibility can be seen as users' belief in the consistency of using SWD with the way they live. Previous research also demonstrated that the importance of Compatibility to the adoption of new technologies (e.g., e-banking [23]). Furthermore, Gao et al. [16] also confirmed that compatibility was one of the important determinants to influence older adults adoption of smartphones in China. Therefore, the following hypotheses were proposed.

H1: The PEOU has a positive effect on users' PU towards SWD.
H2: The PU has a positive effect on users' attitude towards SWD.
H3: The PEOU has a positive effect on users' attitude towards SWD.
H4: The PU has a positive effect on users' BI towards SWD.
H5: The attitude has a positive effect on users' BI towards SWD.
H6: The compatibility has a positive effect on users' attitude towards SWD.

Personal Characteristics (PC). Personal characteristics [14] as key factors of technology diffusion are increasingly being recognized in academic and practitioner communities. Personal characteristics cover many possible constructs, including gender, sex, age, education background and occupation [14]. For example, gender as one aspect of personal characteristics can be an important factor in determining one's consumer behavior. The authors in [34] found that sex influences final judgment obviously. Therefore, we proposed the following hypothesis:

H7: Personal characteristics have a positive effect on the users' attitude towards SWD.
H8: Personal characteristics have a positive effect on to the users' BI towards SWD.

Trust (TU). A potential adopter usually wants to maximize benefits and minimize risks. Trust can help reduce the uncertainties a use faces when using SWD. Previous research has found that trust is one of the important factors to the adoption of online information services (e.g., [20]). In [20], the authors extended TAM with trust in the service provider to study user acceptance of online shopping. They found that trust-related issues have a considerable effect on user acceptance of online shopping.

In [13], the authors found that trust has a positively direct effect on the intention to use mobile information systems in Norway. To better explain the importance of trust to users' attitude towards SWD, we propose the following hypothesis:

H9: Trust has a positive effect on users' attitude towards SWD.

Perceived Risks (PR). Perceived risk is considered as felt uncertainty regarding possible negative consequences of using a product or service. Featherman and Pavlou [10] define perceived risk as the potential for loss in the pursuit of a desired outcome of using an e-service. People are often anxious about the diverse types of risks presented when engaging in activities or functions involved in a new technology. Liebermann and Paroush [25] proved that adoption rates of newly offered goods depend crucially on the marketer's ability to mitigate perceived risk involved with new goods offered. Thus, a user of SWD may be deterred from increasing usage due to perceived risk of the new technology. Previous research suggests that perceived risk is an important construct to affect users' attitude towards new technologies (e.g., [9]). For example, Donthu and Garcia [9] found that Internet shoppers are less risk averse than Internet non-shoppers are. Wu and Wang [37] found the positive influence of perceived risk on behavioral intention to use mobile commerce. The implicit uncertainties involved in using SWD have rendered risks as inevitable elements. Therefore, we proposed the following hypothesis:

H10: The perceived risks have a negative effect on users' attitude towards SWD.

4 An Empirical Study

In this empirical test, our research model was examined through the use of SWD in China.

4.1 Instrument Development

The validated instrument measures from previous research were used as the foundation to create the instrument for this study. Previous studies were reviewed to ensure that a comprehensive list of measures were included. In order to ensure that the instrument better fit this empirical study, some minor words changes were made to ensure easy interpretation and comprehension of the questions. All the items were adopted from prior studies ([7, 10, 14, 20, 32, 35]) and modified to fit the domain of using SWD. A questionnaire was developed first in English and then translated into Chinese. Back-translation was conducted by bilingual third parties to improve the translation accuracy. As a result, 26 measurement items[1] were included in the questionnaires. In addition, a seven-point Likert scale, with 1 being the negative end of the scale (strongly disagree) and 7 being the positive end of the scale (strongly agree), was used to examine participants' responses to all items in the survey.

[1] The measurement items are available at this link: http://tinyurl.com/jtclbxy.

4.2 Samples

The data for this study was collected through paper-based questionnaires from 20th Dec to 30th Dec 2015 in the residential area in the biggest city in the central China. People were asked to participate in the survey voluntarily. Firstly, we explained who we were, what they were supposed to do during our survey, and the purpose of the survey. The participants were also informed that the results would be reported only in aggregate and their anonymity would be assured. After participants experienced the SWD, they were asked to complete the questionnaires and submitted them to us. 180 completed questionnaires were collected, among which 145 of them were valid questionnaires (i.e., valid respondent rate 80.6 %). Among the participants, 67 of the participants were male, and 78 were female. In terms of age, 68 participants were 25 years old and under 25 years old, while 77 participants were over 25 years old.

4.3 Measurement Model

The quality of the measurement model is determined by (1). Content validity, (2). Construct reliability and (3). Discriminant validity [2]. To ensure the content validity of our constructs, a pre-test of the questionnaire with 3 researchers in the field of information systems was conducted in Oct 2015. And we found that the questionnaire was well understood by all the researchers.

To further test the reliability and validity of each construct in the research model, the Internal Consistency of Reliability (ICR) of each construct was tested with Cronbach's Alpha coefficient. As a result, the Cronbach's Alpha values range from 0.615 to 0.977. Robinson et al. [31] indicated that a reliability coefficient of 0.6 was marked as a lowest acceptable limit for Cronbach's Alpha for exploratory research. All the constructs in the research model were above 0.6. Consequently, the scales were deemed acceptable to continue.

Convergent validity was assessed through composite reliability (CR) and the average variance extracted (AVE). Bagozzi and Yi [3] proposed the following three measurement criteria: factor loadings for all items should exceed 0.5, the CR should exceed 0.7, and the AVE of each construct should exceed 0.5. As shown in Table 2, all constructs were in acceptable ranges.

The measurements of discriminant validity were presented in Table 3. According to the results, the variances extracted by the constructs were more than the squared correlations among variables. The fact revealed that constructs were empirically distinct. As good results for convergent validity and discriminant validity were achieved, the test result of the measurement model was good.

4.4 Structural Model and Hypotheses Testing

The structural model was tested using SmartPLS. Table 4 presents the path coefficients, which are standardized regression coefficients. Seven (H1, H2, H3, H4, H5, H6, H9) of the ten research hypotheses were significantly supported. According to the results, perceived ease of use, perceived usefulness, trust and compatibility were found to have

Table 2. Means, Factor loadings, Composite reliability, and AVE for each item

Construct	Item	Factor loading	Composite reliability	AVE	Cronbach's Alpha
Perceived usefulness	PU1	0.858	0.893	0.677	0.937
	PU2	0.836			
	PU3	0.800			
	PU4	0.795			
Perceived ease of use	PEOU1	0.814	0.867	0.684	0.977
	PEOU2	0.845			
	PEOU3	0.822			
Compatibility	COM1	0.844	0.879	0.708	0.810
	COM2	0.818			
	COM3	0.861			
Personal characteristics	PC1	0.591	0.839	0.656	0.836
	PC2	0.922			
	PC3	0.521			
	PC4	0.561			
Perceived risks	PR1	0.931	0.802	0.588	0.615
	PR2	0.808			
	PR3	0.595			
Trust	TU1	0.700	0.878	0.592	0.782
	TU2	0.804			
	TU3	0.689			
	TU4	0.838			
	TU5	0.804			
Attitude	PR1	0.940	0.935	0.878	0.861
	PR2	0.933			
Behavior intention	BI1	0.919	0.901	0.820	0.854
	BI2	0.892			

Table 3. Discriminant validity

Variables	AT	BI	COM	PC	PEOU	PR	PU	TU
AT	0.9							
BI	0.7	0.9						
COM	0.6	0.5	0.8					
PC	−0.1	−0.2	−0.1	0.5				
PEOU	0.5	0.5	0.7	−0.1	0.8			
PR	0.1	−0.0	0.1	0.1	0.2	0.8		
PU	0.5	0.5	0.7	−0.1	0.7	0.1	0.8	
TU	0.6	0.5	0.6	−0.0	0.6	−0.0	0.6	0.8

Note: Diagonals represent the average variance extracted, while the other matrix entries represent the squared correlations.

Table 4. Test of hypotheses based on path coefficient

Hypothesis	Path coefficient	Hypothesis result
H1: PEOU to PU	0.693[a]	Supported
H2: PU to AT	0.343[a]	Supported
H3: PEOU to AT	0.327[a]	Supported
H4: PU to BI	0.233[b]	Supported
H5: AT to BI	0.549[b]	Supported
H6: COM to AT	0.368[b]	Supported
H7: PC to AT	−0.093	Not Supported
H8: PC to BI	−0.109	Not Supported
H9: TU to AT	0.4[b]	Supported
H10: PR to AT	0.052	Not Supported

[a]$p < 0.05$; [b]$p < 0.01$; [c]$p < 0.001$.

a statistically significant effect on users' attitude towards SWD, while perceived risk and personal characteristics did not have significant impact on users' behavior of using SWD.

The R^2 (R square) denotes to coefficient of determination. It provides a measure of how well future outcomes are likely to be predicted by the model, the amount of variability of a given construct. In our analysis, the R^2 coefficient of determination is a statistical measure of how well the regression coefficients approximate the real data point. According to the result, the amount of variance in Behavior Intention was 0.466, which means the explained variance of Perceived Usefulness factor is 46.6 %. Similarly, the percentage of variance explained for attitude is 50.6 %. The percentage of variance explained for PU is 48 %.

5 Discussion

The findings of this empirical study provided some insights on the adoption of SWD to assist healthcare to both researchers and practitioners in China. On the one hand, from an academic perspective, this study contributed to the literature on the adoption of SWD by identifying and validating the potential factors affecting the adoption of SWD by identifying and validating the potential factors affecting the findings demonstrated the appropriateness of the research model and hypotheses for measuring the adoption of SWD. On the other hand, from a business perspective, the statistical results of the research model also provided some insights for practitioners to offer better SWD with a high user acceptance in China.

According to the results, we found that 7 research hypotheses were supported. PU (0.343), PEOU (0.327), compatibility (0.368), Trust (0.433) explain 50.6 % of the observed variance in users' attitudes toward SWD. Both PU and PEOU have significant positive impacts on users' attitude towards SWD. This is consistent with the findings from previous study (e.g., [22]).

This study also has some practical implications. The results of this empirical test also provided guidelines and suggestions to services providers. The influence of trust on users' attitudes towards SWD was the most significant which is followed by compatibility, PU and PEOU. Thus, when considering the customers' attitude towards SWD, the companies should pay more attention the trust construct. The devices should be able to provide precious measurements and send some essential health-related messages timely. Users also expected that the primary care units are able to provide services to patients by taking advantage of SWD. Furthermore, it is essential to make sure that it is easy to use SWD.

To better understand the findings of this study, an interview with a doctor from local primary care unit was carried out in February 2016. The interviewee indicated that the primary care in China was far away from what it is like in developed countries (e.g., Sweden and Canada). While they have a proper system to care about every citizen, we are in desperate need more investments on infrastructure construction. Primary care services (e.g., home care) were provided in theory. However, it hasn't been applied to the real setting in most residential areas. Most doctors and nurses have too many patients in their units. Therefore, they did not get time to visit patients' homes. The interviewee also indicated that collecting citizens' daily health data like heartbeats and heart rate do help doctors a lot when making a definite diagnosis in the long term. However, this requires nearly all citizens to use SWD in appropriate ways. In addition to this, a sound database must be constructed to collect and analyze all those information that come from the patients. Otherwise, the collected data will become a string of numbers, which is meaningless to the doctors. They are often too busy to find out the meanings behind the numbers. Lastly, he indicated that another essential precondition for the widespread of SWD to assist healthcare in China: the support from the government. Therefore, it is believed the government plays an important role in the success of the promotion of using SWD to assist healthcare in China.

However, we were also aware of some limitations. Firstly, we only tested the research model and research hypotheses with samples from one of the big cities in China. This sample might not be fully representative of the entire population in China. Secondly, all the data were collected using self-reported scales in the research. This may lead to some caution because common method variance may account for some of the results. This has been cited as one of the stronger criticisms of tests of theories with TAM and TAM-extended research [27]. However, our data analysis with convergent and discriminant validity does not support the presence of a strong common methods bias.

6 Conclusion and Future Research

This research was designed to explore users' adoption of SWD to assist healthcare in China. A research model with ten research hypotheses was proposed. The results indicated that seven of the ten research hypotheses were significantly supported. And the most significant determinant for users' attitude towards SWD was trust. However, personal characteristics did not have a significant positive impact on both users' attitude and behavior intention to use SWD.

Continuing with this stream of research, we plan to examine some additional constructs' influence on the adoption of SWD. Future research is also needed to empirically verify the research model with larger samples across China.

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