Wearable Technologies: Acceptance Model for Smartwatch Adoption Among Older Adults

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Abstract. Wrist-worn wearable technologies such as smartwatches are seen to be one of the breakthrough devices that would help older adults age successfully. However, to date, there is still a lack of systematic evaluation of smartwatch adoption for older adults. Thus, in order to gain a better understanding of older adults' attitude towards the acceptance of wearable technologies, a user acceptance model was proposed by extending the previously validated Technology Acceptance Model (TAM). A 26-item Likert-type questionnaire was administered to 76 older adults, aged 50 to 74, following the actual demonstration of the usage and features of two smartwatches (Samsung Galaxy Watch 42 mm and MiBand 4). Results reveal that prior experience, affective quality and technology-related anxiety affected older adults' perception of ease of use. While social support impacted their attitude, accessibility had an effect on their intention to use the smartwatch. These results provide a good insight with regards to the acceptability factors for smartwatch adoption among older adults.

Keywords: Smartwatch · Older adults · Technology Acceptance Model · Wearable technology

1 Introduction

Over the years, the population of older adults is significantly increasing leading to a dramatic demographic shift that raises concerns across different sectors. According to the recent demographic research, the global population of older adults aged 60 years and above reached 962 million in 2017, which is more than twice as large as in the record in 1980 (World Population Ageing 2017). It is predicted that by 2050, the number of older persons will be doubled and would reach nearly 2.1 billion which will eventually outnumber the population of adolescents and youth aged 10–24 (World Population Aging 2017). These changes in demographic ratio present both opportunities and challenges for existing health care systems, mental health services, psychological research, government sectors and many more.

One of the solutions being proposed to address the increasing needs of the older population is through the use of technology and information systems. To date, there are a lot of different types of technology being developed in order to aid the needs

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of older adults in the most efficient way possible. One of which is the development of wrist-worn wearable technology, which people often refer to as 'smartwatch', for health care assistance, monitoring and communication (Muchna et al. 2018; Piwek et al. 2016). Despite the fact that some studies have already proved the potential benefits of smartwatches for older adults, the evaluation of this type of technology in the perspective of user acceptance is seemingly neglected in research (Kim and Shin 2015; Peek et al. 2014). There are existing user acceptance researches but only a few of them focused on the older population, and among those few, only a couple of researches focused on wrist-worn wearable technologies. Additionally, most of the studies in this area are exploratory in nature, thus further studies are considered essential. Therefore, this study aims to examine different key factors (i.e. affective quality, tech-related anxiety, prior experience, perceived usefulness, perceived ease of use, accessibility, and social support) that are closely associated with older adults' perception and attitude towards wrist-worn technologies. This study aims to bridge the gap in the literature by developing a user acceptance model for smartwatch adoption among older adults through extending the previously established Technology Acceptance Model (TAM).

2 Background & Related Work

2.1 Older Adults and Smartwatch Adoption

Older Adults. The increase in population trend of the elderly has led a lot of researchers, designers and scholars to shift their attention to this specific population in order to address their increasing needs (Schulz et al. 2014). Nowadays, interest in technology for older adults have been gaining notable attention in the research field due to several reasons (see Schulz et al. 2014). Despite the growing attention, the elderly are still under-considered in the field of technological advancement and there is still a persisting stereotype that older people are viewed as "non-technological", "non-adapters" or "technology laggers" (Lee and Coughlin 2015; Conci et al. 2009). Although it is expected that older people may have a different approach towards technology in comparison to the younger generation because of the differences in sensory, motor, and cognitive ability mostly due to the effects of aging, this does not equate to older people fully rejecting the use of technology (Conci et al. 2009). In fact, there are several studies that proved that older adults may be open and accepting of different technologies under several conditions (Lee and Coughlin 2015; Peek et al. 2014; Lewis and Neider 2017). According to the findings of Czaja and his colleagues (2006), older adults' relationship with technology is much more complex than the preexisting stereotype that older adults are just generally afraid and unwilling to use any technology (as cited in Mitzner et al. 2010). In order to shed light upon this complexity, further investigation is considered to be essential.

Smartwatch Adoption. With the rapid development of technology, miniaturization, and the mass production of cheaper, smaller and faster electronic parts, digital watches have evolved from a simple machine that tells the time and date to a small but complex machine with smart and computer-like features (Kim and Shin 2015). For the past few years, wrist-worn wearable technologies or smartwatches have been considered to possess great potential for the future of technological advancements (Lewis and Neider

2017). A small percentage of the available smartwatches in the market today are geared towards the older population. Most of the smartwatches for older adults possess some common features such as GPS location tracking system, physical condition monitoring system (e.g. ECG, body temperature etc.), activity. monitor, fall-risk alert, emergency alert and motion sensor (Saner 2018; The Best Senior Wearables and Trackers 2018; Piwek et al. 2016) These features offer great potential for older adults to help them in their day-to-day living and increase their feelings of independence and quality of life (Saner 2018; Piwek et al. 2016). For example, in a review conducted by Cooper and her colleagues (2018), it was concluded that wearable fitness trackers with accelerometer increased physical activity among older adults. However, despite its promising features studies regarding smartwatches in older adults are more focused on enhancing its features and designing it according to their needs and capacities rather than focusing on the consumers' perspective. One of the few studies that taken user acceptance into account, is a study by Mercer and colleagues (2016) which concluded that following the TAM, smartwatches are perceived to be useful and acceptable by older adults with chronic illness. However, the researchers also suggested that more research needs to be carried out in order to fully explain smartwatch acceptance among older adults.

2.2 Technology Acceptance Model (TAM)

As different kinds of technology continue to develop throughout the years, various theoretical models were proposed in order to explain technology adoption. One of the most prominent and extensively utilized models for technology adoption is the Technology Acceptance Model (TAM). Originally, the model suggests that perceived ease of use (PEOU) and perceived usefulness (PU) are the key determinants to predict user's attitude towards the product (AT) and the user's behavioral intention to use the product (BI) (Davis et al. 1989, 1993). According to this model, when a product is perceived to be easy to use by users in general, the product may be seen to be more useful and the users may have a more positive attitude towards it. In which increased PU and AT leads to an increase in BI.

The TAM has been extensively studied and utilized by many researchers in studying adoption of different types of technologies such as mobile phone (Conci et al. Conci et al. 2009; Joo and Sang 2013; Kim and Sundar 2014), e-learning (Masrom 2007), ICT (Edmunds et al. 2012) and smartwatch (Kim and Shin 2015). This model has also been utilized in studies for technology adoption for older adults (Conci et al. 2009; Lee and Coughlin 2015). The model's variables and its predictive power have been validated multiple times across different studies. Therefore, this study aims to adopt this model as the foundation of the theoretical framework for investigating the user-acceptance of wrist-worn wearable technology among older adults. Following the original model, the researcher proposes that:

H1. AT will be positively correlated with BI
H2. PU will be positively correlated with AT
H3. PEOU will be positively correlated with AT
H4. PEOU will be positively correlated with PU

2.3 Factors Affecting Smartwatch Adoption in Older Adults

Prior Experience (PE). In general, the perception of technology is affected by prior experiences (Walsh and Callan 2010). In order to understand the use and value of new technology, people tend to rely on the familiarity of the technology based on their previous experiences (Brown and Venkatesh 2005; as cited in Lee and Coughlin 2015). As noted in the review of literature conducted by Lee and Coughlin (2015) previous exposures play a bigger role among older adults than their younger counterparts. Moreover, the causal relationship between past experience is said to be stronger for older adults as well (Niemelä-Nyrhinen 2007; Quinn, 2010; as cited in Lee and Coughlin 2015). Extending this assumption to wearable technology, one study found that wearable activity trackers may be less useful for individuals who are less familiar with mobile technology (Mercer et al. 2016). Thus, PE is seen as an important factor that shapes individuals', especially older adults', perception towards the use of new technology. In a previous study, PE was found to affect PEOU and is considered to be a key factor in determining future usage of a product (Bajaj and Nidomolu 1998; as cited in Saade and Kira 2007). Therefore, it is hypothesized that:

H5. PE will be positively correlated with PEOU

Affective Quality (AQ). AQ is seen to be a very important aspect of product design. The affective quality is the ability of a product to evoke specific impression, feelings and emotions from the users, which affects how the users perceive a certain product (Yanagisawa 2011). There are several studies that assert that AQ has a positive effect on technology-related user acceptance. For example, in a study conducted by Zhang and Li (2005), it was concluded that perceived AQ significantly affects how university students perceived the ease of use of a newly created website. Additionally, one study revealed that the user's perception and rating of usability were heavily influenced by their judgment of its perceived hedonic or affective quality (Harbich and Auer 2005). Furthermore, AQ is also said to be an important factor for older adults in determining their acceptance attitude towards technology (Lee and Coughlin 2015). Extending these findings into smartwatches, this study predicts that AQ will play a significant role in older adults' perception towards smartwatches. Thus, predicting the following hypotheses:

H6. AQ will be positively correlated with PEOU

Technology-Related Anxiety (TRA). TRA, or sometimes called as more specifically computer anxiety, is concept-specific anxiety that is associated with a person's interaction with technology or computers (Oetting 1983; as cited in Saade and Kira 2007). It is basically the tendency of a person to experience a level of uneasiness over his or her impending use of a technological product. Technology-related anxiety is not only experienced by older adults but the younger generation as well (see Saade and Kira 2007). However, it was found that older adults generally have lower self-confidence and are more anxious in interacting with high-tech devices than younger people (Lee and Coughlin 2015). In an in-depth study regarding older adults' experience with interactive technology conducted by Turner and his colleagues (2007), it was found that older adults think that they are "too old" for technology and they feel anxious and alienated towards

it (as cited in Barnard et al. 2013). Comparatively, according to the study conducted by Czaja and his fellow researchers (2006), it was found that low self-efficacy regarding computer use and high anxiety for computer use are the two most significant personal barriers to technology adoption for older adults (as cited in Mitzner et al. 2010). Thus, TRA is an important factor in technology adoption for older adults. Several studies have related TRA with PEOU (Saade and Kira 2007; Phang, et al. 2006; Venkatesh 2000), and PU (Heerink et al. 2012). Therefore, it is hypothesized that:

H7. TRA will be negatively correlated with PEOU

H8. TRA will be negatively correlated with PU

Social Support (SS). SS is seen as an essential factor for older adults to overcome barriers to technology adoption (Lee and Coughlin 2015). Much like for younger people, older adults also seem to rely on their peers and family with regards to the validation of behaviors, which includes the purchase and use of technology. People who are within older adults' social groups play an important role in the technology adoption process (Wang et al. 2010; as cited in Lee and Coughlin). In a study conducted by Conci and colleagues (2009) it was found that social factors such as social pressure and social support are considered to be an important factor towards older adults' adoption of mobile phones. Similarly, in a more recent study, it was found that pre-implementation acceptance of technology of older people also depends on social factors since family, friends, professional caregivers, and peers are all described as having an influence (Peek et al. 2014). With this notion, the researcher predicts that:

H9. SS will be positively correlated with AT

Accessibility (ACC). ACC refers to whether technology is perceived as easy to obtain (Kothgassner et al. 2012; as cited in Disztinger et al. 2017). In general, ACC is considered to be an important factor in technology adoption. Basically, adoption is less likely to happen if the product is not effectively delivered into the market. This notion is important to consider especially in the case of older adults because according to research older adults are generally less aware of new technologies, even the ones which are specially designed for them (Heinz et al. 2013). This lack of awareness and knowledge can act as a barrier to adoption (Tanriverdi and Iacono 1999; as cited in Lee and Coughlin 2015). In a study regarding assistive technologies, ACC was found to be a mediating factor between older adults and technology use (McCreadie and Tinker 2005). In addition to this, there are also a lot of studies that relate ACC to technology adoption (Kim and Shin 2015; Wixom and Todd 2005) and behavioral intention to use VR technology (Disztinger et al. 2017). Thus, extending this literature to smartwatches for older adults, it is proposed that:

H10. ACC will be positively correlated with BI

2.4 Summary

After an extensive review of related journals and articles, the research assumptions of this study and its proposed acceptance model for smartwatch adoption among older adults are summarized by the illustration below (Fig. 1):

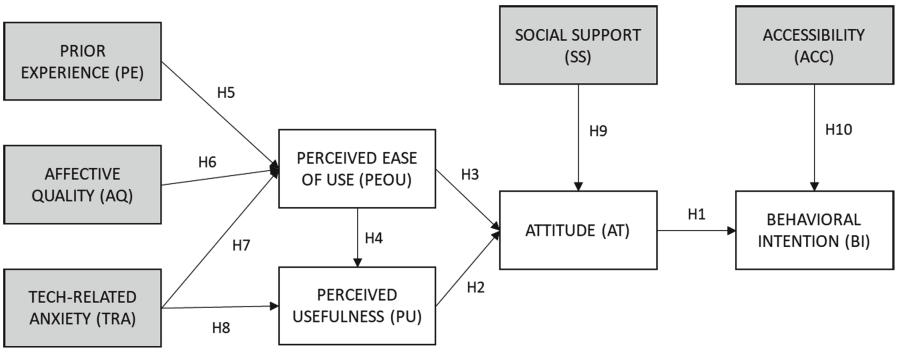

Fig. 1. Proposed acceptance model for smartwatch adoption among older adults

3 Methodology

3.1 Participants and Procedure

A total of 76 older adults (40 male, 36 female) participated in an experiment which involves an actual demonstration of the usage and features of a smartwatch (Samsung Galaxy Watch 42 mm and MiBand 4). The average age of the participants was 57.6 (Min = 50, Max = 74, SD = 5.83). Before the experiment, 37% of the participants declared that they do not have any knowledge about smartwatches while 63% said they did. Moreover, 87% declared that they haven't had any experience of using smartwatches and only 13% had actual experience.

The actual demonstration includes informing the participants about some basic information with regards to the usage, procurement and features of the smartwatch which includes personalization, communication features, health-related features and etc. After the actual demonstration, the participants were given some time to experience and test the smartwatch by themselves and then followed by an administration of a 26-item, 5-point Likert-type survey designed to test the proposed model.

3.2 Questionnaire

The administered survey was a combination of items from previously validated questionnaires and researcher-made questions. Questionnaire items for PEOU, PU, AT and BI were adopted from the questionnaire used from previous TAM studies (Davis 1989, 1993; Venkatesh et al., 2003; Kim and Sundar 2014). Items for AQ was adopted from

Table 1. Questionnaire for the proposed acceptance model

Construct	Item
Prior experience	
PE1	I have used several technological devices (e.g., smartphone, tablet PC) before
PE2	I know how to use smartwatch pretty well
Affective quality	
AQ1	I feel excited when using this smartwatch
AQ2	This smartwatch is attractive and pleasing
Tech-related anxiety	
TRA1	I feel uncomfortable when using high-tech products
TRA2	I feel that I will be more uncomfortable if I use a smartwatch
TRA3	I am anxious about adopting new technologies
Social support	
SS1	I can get help from my family or acquaintance when using a smartwatch
SS2	I have technological or economic support to use this smartwatch
Accessibility	
ACC1	I have seen people use smartwatch frequently
ACC2	I know where to purchase a smartwatch
Perceived usefulness	
PU1	Using this smartwatch helps me productively complete my tasks
PU2	Using the smartwatch helps me effectively do my job
PU3	This smartwatch is useful in doing my job
PU4	Using this smartwatch improves my ability to complete my tasks
PU5	Using this smartwatch makes it easier to complete my tasks
Perceived ease of use	
PEOU1	Operating this smartwatch is easy for me
PEOU2	I find this smartwatch easy to use
PEOU3	Using this smartwatch does not require a lot of my mental effort
Attitude	
AT1	Using this smartwatch is a good idea
AT2	I have a generally favorable attitude toward using this smartwatch
AT3	I like the idea of using this smartwatch
AT4	Overall, using this smartwatch is beneficial
Behavioral intention	
BI1	I predict I will use this smartwatch in the future
BI2	I plan to use this smartwatch in the future
BI3	I expect my use of this smartwatch to continue in the future

the measures developed by Kim and Sundar (2014). Lastly, items for TRA, PE, SS and ACC were constructed by the researchers for this study (Table 1).

The survey items were randomized to create three unique versions (set A, B and C) for counterbalancing and eliminating the order effects.

3.3 Data Analysis

The data was analyzed through confirmatory factor analysis (CFA) and structural equation modelling (SEM) using AMOS 26 statistical software, with a maximum likelihood estimation method. CFA was used for both the reliability and validity measurements of the proposed factor structure, while SEM was used in order to analyze the strength and direction of the hypothesized causal paths among the constructs.

4 Results

This study employed confirmatory factor analysis (CFA) and structural equation modelling (SEM) to test the proposed model and corresponding hypotheses.

The structural equation model results showed that some of the measurement model's fit indices are found to be acceptable considering the small sample size: ratio of $\chi 2$ to the degrees of freedom ($\chi 2/df$) = 1.788, goodness-to-fit index (GFI) = 0.832, and root mean square error of approximation (RMSEA) = 0.078. Furthermore, as depicted in Fig. 2, it was revealed that the standardized coefficients of all proposed paths were significant at $p = 0.05$, PU and AT path was significant at $p = 0.10$, except for the PEOU and AT path (H3, $\beta = -0.797$, $p = 0.189$).

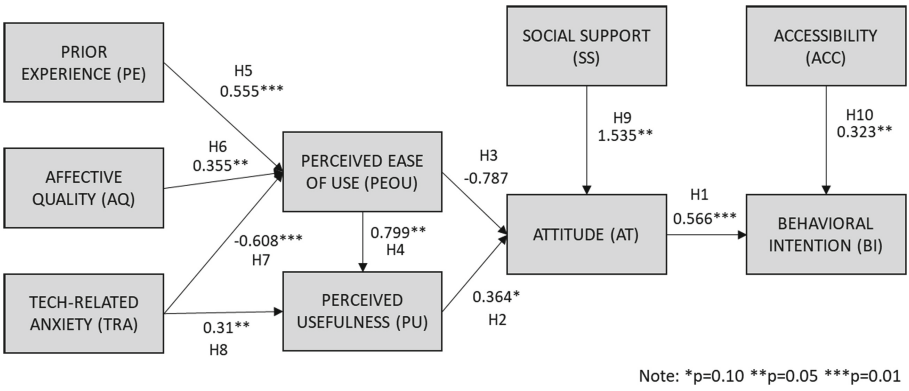

Fig. 2. Structural equation modelling results

The structural equation modeling results are shown in Fig. 2. The summary of the path coefficients and results of the hypotheses testing are shown in Table 2. From the results, it is found that attitude was a significant factor influencing behavioral intention to use (BI) ($\beta = 0.566$, $p < 0.01$), supporting the first hypothesis. Moreover, perceived usefulness

(PU) appeared to have a significant causal relationship with AT ($\beta = 0.364$, $p < 0.05$). However, even though perceived ease-of-use (PEOU) significantly influenced PU ($\beta = 0.799$, $p < 0.001$), it did not have a direct influence on AT as expected ($\beta = -0.787$, $p > 0.10$). Prior technology-related experience (PE) significantly had an effect on PEOU ($\beta = 0.555$, $p < 0.001$.). Similarly, affective quality significantly impacted PEOU ($\beta = 0.355$, $p < 0.05$.). As expected, technology-related anxiety was negatively correlated with PEOU ($\beta = -0.608$, $p < 0.001$.). Initially, it was expected that TRA would also have a negative correlation with PU as well, however, the relationship appeared to be positive ($\beta = 0.310$, $p < 0.05$.). On the other hand, social support (SS) significantly affected AT ($\beta = 1.535$, $p < 0.05$.) and accessibility (ACC) directly affected BI ($\beta = 0.323$, $p < 0.05$.). In summary, eight of the initial hypotheses were accepted and two were rejected.

Table 2. Summary of hypothesis tests

Hypotheses	Standardized coefficient	SE	CR	P-value	H_1
H1: AT → BI	0.566	0.553	2.81	0.01	Accepted
H2: PU → AT	0.364	0.094	1.94	0.05	Accepted
H3: PEOU → AT	−0.787	0.310	−1.31	0.19	Rejected
H4: PEOU → PU	0.799	0.206	4.03	***	Accepted
H5: PE → PEOU	0.555	0.108	3.43	***	Accepted
H6: AQ → PEOU	0.355	0.186	2.27	0.02	Accepted
H7: TRA → PEOU	−0.608	0.115	−3.78	***	Accepted
H8: TRA → PU	0.310	0.105	2.19	0.02	Rejected
H9: SS → AT	1.535	0.309	2.23	0.03	Accepted
H10: ACC → BI	0.323	0.125	2.37	0.02	Accepted

Note: ***$p < 0.001$

5 Discussion

With the rise of aging societies and the rapid growth of technology, increasing attention has been paid to the research and development of wearable technologies that address the needs of the older population. Wrist-worn wearable technologies such as smartwatches may be one of the breakthrough devices that would help older adults age successfully by keeping their health on track and by being socially connected. With its growing potential, an evaluation of how older adults perceive such technology is essential. In this study, the proposed model was found to have a potential in representing older adults' attitude towards smartwatch adoption. Through this study, it was revealed that older adults have a fairly positive attitude towards the use of smartwatches. During the actual demonstration and trial period, most of the participants displayed interest and reacted enthusiastically.

Previous studies showed that prior technology experience influences older adults' likelihood of adopting emerging technology (e.g., Quan-Hasse et al. 2018). Similarly, based on the results of the analysis, it was revealed that having prior experience in using similar technologies positively affects how they think about smartwatches. More specifically, older adults who had more technology-related experience thought that smartwatches are easy to use. This may be due to the fact that increased technology experience can enhance familiarity and increase the likelihood of acquiring an adequate mental model which allow them to understand the mechanism of the smartwatch with less effort. Thus, making them perceive that it is easier to use.

In addition, similar to the findings of previous studies, products with high affective quality tend to be perceived as more usable than those with low affective quality (Harbich and Auer 2005). The impact of affective quality, in this case, may be explained as a result of a psychological phenomenon called 'halo effect'. This phenomenon occurs when one aspect of a certain object affects how a person perceives the quality of an object overall. Thus, the perception of high affective quality might have led to an overall positive impression, in which it affected the judgment on its usability. However, further research is needed to confirm this claim.

Moreover, it was hypothesized that technology-related anxiety would negatively influence older adults' perception of the usefulness and ease of use of smartwatches. However, despite that both assumptions showed significant results, only the relationship between technology-related anxiety and perceived ease-of-use appeared to be negative. Results show that older adults who experience anxiety towards the use of technology-related products tend to perceive the smartwatch to be complex and hard to use. This result confirms the findings of the previous studies regarding technology adoption (Czaja et al. 2006, Saadé and Kira 2007; Phang, et al. 2006; Venkatesh 2000). Furthermore, this is in line with the recent findings of Tsai and colleagues (2020) whereby it was found that older adults who experience anxiety towards the general use of technology also feel that the use of smart clothing is difficult. Although this finding focused on a different type of technology, this similar finding could signify the crucial role of technology-related anxiety in technology adoption for older adults in general. On the other hand, surprisingly, technology-related anxiety was found to be positively related to the perceived usefulness of the smartwatch. This result could mean that anxiety only affects their perception of the complexity of the device but not its actual value. That even though they experience some sort of anxiety they are still able to find the smartwatch useful. However, information from the questionnaire is not enough to explain that actual cause of the positive relationship, thus, this finding accounts for further investigation.

As hypothesized, social support was seen to have a positive effect on older adults' overall attitude towards the use of smartwatches. However, this finding is not only limited to the adoption of smartwatches. As can be seen from previous findings, the impact of social support is rather general and has been applied to various technologies (e.g. Wang et al. 2010; Conci et al. 2009). Similarly, it was mentioned by Lee and Coughlin (2015) that social support plays an important role in technology adoption for older adults. Thus, it is important to note that, in order for older adults to adopt wearable technology successfully, people inside their social circle such as family and friends should also have a positive attitude towards smartwatch as well.

By the same token, accessibility was positively related to older adults' intention to actually use the smartwatch. This confirms previous findings whereby accessibility impacted older adults' technology use (McCreadie and Tinker 2005).

Lastly, the original TAM showed good relationship values except for the PEOU and AT path. This could indicate that for older adults, their attitude towards wearable technologies is not dependent on the usability of the product. This could mean that even though some older adults think that smartwatches are difficult or complicated, it does not mean that they think that it is not useful. This interesting result accounts for further investigation. This could mean that some aspects of the original TAM is not applicable to certain population, such as older adults.

6 Conclusion

Overall, the proposed model displays a huge potential in identifying key factors that affect older adults' adoption to technology, specifically in smartwatches. Findings from this study are not only limited to smartwatches but with continuous investigation, it can also be applied to different wearable technologies as well. However, this study is not without its limitations. First and foremost, the number of participants is relatively low to conduct structural equation modeling. Testing the model to a larger number of participants would verify and further confirm the results of this study. Moreover, the participants were only given a limited amount of time to test and learn about the smartwatches. It might be better for future researchers to consider extending the trial period to have a better grasp of older adults' attitude and perception of such devices. Additionally, participants in the present study included older adults aged 50 and above. Although the age-range of this particular population differs across studies, to some, this range may be a little broad to determine the older adult population. Thus, future studies could consider narrowing down the range to have a better focus on the target population. In conclusion, despite some certain limitations, the present study provides a good insight with regards to the acceptability factors for smartwatch adoption among older adults.

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