Universal Access in the Information Society (2024) 23:203–212
https://doi.org/10.1007/s10209-022-00933-4

LONG PAPER

Staying connected: smartphone acceptance and use level differences of older adults in China

Xiaowen Zhu[1] · Xianping Cheng[2]

Accepted: 3 October 2022 / Published online: 13 October 2022

Abstract

In recent years, an increasing number of studies have addressed the older adults' Information and Communication Technology acceptance, the majority of which concentrate on the use of computers and the internet. As smartphone use becomes further integrated into older adults' daily lives, it is important to investigate how perceptions about and use of smartphones intersect. This study (1) proposes an extended Technology Acceptance Model and tests the relationships between Perceived Usefulness, Perceived Ease of Use, Attitude, Behavioural Intention, Self-efficacy, Technology Anxiety, and Social Support in older adults' smartphone use by confirmatory factor analysis (CFA); and (2) analyses the specific differences between primary, medium, and advanced use level groups in each construct by Q-cluster and ANOVAs. We conduct a community-based survey with a sample of 1,006 older adults in East China. The data demonstrate that the extended model offered a good explanation of smartphone acceptance among the older adults, and the groups belong to different use levels show significant difference in all constructs. The findings indicate that digital divide is objectively inevitable in smartphone use, but the older adults are extremely diverse groups that do not uniformly conform to technology averse stereotypes.

Keywords Smartphone use · Technology Acceptance Model · Older adults · Different use levels

1 Introduction

Today, Information and Communication Technology (ICT) is playing an essential role in people's daily lives, including the lives of older adults [1]. In the last two decades, the capabilities and functions of ICT have significantly advanced, particularly in terms of mobility and availability [2]. The smartphone, which has been rated as the most ubiquitous ICT, is characterised by its advanced capabilities and sophisticated hardware. It offers advanced functions and services that generally require a touchscreen and progressive computing capabilities, including an advanced mobile operating system that supports the downloading and running of applications [3]. With the global rise in ageing populations, older adults are increasingly using various technologies to enhance their quality of life, to maintain health, and to keep pace with developments in society [4, 5]. Smartphones are widely adopted by older adults for the purposes of entertainment, health care, online learning, cognitive skill improvement, social interaction, and many others [6]. Smartphones are today crucial for active engagement in a variety of everyday life tasks and societal participation [7], and non-use may lead to digital exclusion and even unequal treatment.

During the COVID-19 pandemic in China, people who access indoor public spaces (e.g. shopping mall, supermarket, and restaurant) and public transport (e.g. underground and train) need to show a personal QR code on their smartphone as a health certificate. This has created many daily obstacles for older adults. As this problem emerges, discussion and solution to the digital divide and inequality in their smartphone use becomes a priority.

✉ Xiaowen Zhu
zxwswu@126.com

[1] School of Education, Suzhou University of Science and Technology, 99, Xuefu Rd, Huqiu District, Suzhou, China

[2] Lifelong Education Department, Zhejiang Open University, Hangzhou, China

2 Smartphone use and digital divide in older adults

In China, the smartphone consumer market has been one of the fastest developing novel markets in the ICT market since 2000. By the end of 2020, 99.2 per cent of internet access devices were smartphones, and the number of users exceeded 932 million, 22.8 per cent of whom were aged 50 and above [8]. Smartphones cannot only become powerful assistive technologies to help them maintain independence, social participation, and sense of worth in the face of declining physical conditions or limited capabilities [2, 9, 10], but also offer new and empowering opportunities to improve well-being and quality of life [1, 11].

With the increase of older adult engagement, social stereotypes reinforce the problematic generalization that they cannot master smartphones easily [12]. Age-related problems, such as declining eyesight and arthritis, are major challenges to overcome when viewing phone screens and using keypads. These have brought about a significant age-based divide between the young and the old [12, 13]. The existing differences in the ways that individuals use and accept their ICTs and innovative technologies are associated with characterizations termed as 'the digital divide', and unequal access to smartphones has led to significant inequalities in benefit from the digital environment [13, 14]. For older adults, the digital divide in smartphone use is mainly reflected in financial obstacles, lack of access to related skills, lack of self-confidence, cognitive anxiety, and worries about difficulties in finding assistance or support [15, 16]. Smartphone may exacerbate existing individual anxiety [17], sources of inequality and social exclusion [9].

3 Model and hypotheses development of smartphone use

3.1 Technology acceptance model

Bearing in mind the benefits and drawbacks of ICT use of older adults, many studies have attempted to identify the impact factors and evaluate the effects of ICT acceptance. In the last few decades, the research interest in addressing this phenomenon has resulted in the development of numerous theories and models of technology acceptance and its effective usage [18]. The Technology Acceptance Model (TAM) and its extension are the measurement most commonly used by scholars [10, 11, 17]. TAM, originally introduced by Fred Davis [19, 20], is based on the Theory of Reasonable Action (TRA) proposed by Fishbein and Ajzen [21] and the Theory of Planned Behaviour (TPB) developed by Ajzen [22]. It is a dominant model used to clarify and anticipate the effects on individuals of technology acceptance [16]. In the basic TAM, *Perceived Usefulness* and *Perceived Ease of Use* are indicated as fundamental and distinct constructs that are influential in decisions about whether to use information technology [10, 19], and play a mediating role in the complex relationship between system characteristics (external constructs) and potential system usage (attitude and behavioural intention) [23]. Henceforth, in some studies, the extensive versions of TAM have also been proposed to adapt to different research objectives, such as by adding constructs such as Effort Expectancy, Learning Difficulty Perception, and Social Influence [2, 15].

Considering the existing literature and the primary goals of our study, three corresponding study questions were formulated:

- Is the proposed extended TAM suitable in older adult smartphone use?
- How do the additional constructs (*Self-efficacy*, *Technology Anxiety*, and *Social Support*) affect older adults in smartphone use?
- Is there any difference between different smartphone use levels on each construct?

The hypotheses of the basic TAM are:

H1 *Perceived Usefulness* has a positive impact on attitudes towards smartphone use for older adults

H2a *Perceived Ease of Use* has a positive impact on *Perceived Usefulness* for older adults

H2b *Perceived Ease of Use* has a positive impact on *Attitude* for older adults

H3 *Attitude* has a positive impact on *Behavioural Intention* for older adults.

3.2 Additional Constructs and Hypotheses

The main focus of TAM is to explain the determinants of technology use in different groups of participants in different contexts [16]. It is a frequently employed model to systematically investigate the use and acceptance of ICT by older adults [16, 24]. Therefore, in this study, some external constructs which are supposed to have an impact on older adults' smartphone acceptance are proposed and verified in an extended version of the TAM. *Self-efficacy* is defined as the belief in one's capabilities to organise and execute the courses of action required to produce given

attainments [25]. It involves forward thinking about judgments based on beliefs about personal capability [26]. In the present study, *Self-efficacy* refers to the belief of older adults that they could complete a specific task (with a smartphone) given a set of circumstances. It has been considered as an antecedent of *Perceived Ease of Use* and *Perceived Usefulness* in many studies [27, 28]. Considering the previous outcomes, *Self-efficacy* is hypothesised to have a positive relationship with *Perceived Usefulness* and *Perceived Ease of Use* in our study:

H4a *Self-efficacy* has a positive impact on *Perceived Usefulness* for older adults

H4b *Self-efficacy* has a positive impact on *Perceived Ease of Use* for older adults.

Technology Anxiety refers to all digital technology-related negative emotions or feelings and is another commonly used antecedent factor in the TAM [27, 28]. It occurs due to the lack of prior experience in effectively controlling technology [29], and specifically focuses on the user's sense of fear, apprehension, and hope regarding their ability and willingness to adopt technology-related tools [30, 31]. *Technology Anxiety* is one of the most prominent features of stereotypes of technology use in older adults, and it could be easily extended to apply in smartphone acceptance. In accordance with prior studies [1, 16, 32], we postulate a negative relationship between *Technology Anxiety* and *Perceived Ease of Use*, as well as between *Technology Anxiety* and *Perceived Usefulness*:

H5a *Technology Anxiety* has a negative impact on *Perceived Usefulness* for older adults

H5b *Technology Anxiety* has a negative impact on *Perceived Ease of Use* for older adults.

Social Support refers to the provision by social networks of psychological and material resources to strengthen one's ability to cope with technological stress and problems [1, 11, 33]. According to previous studies on the adoption of ICT by older adults, it is usually provided by family members and peers [28, 34, 35], in the form of instrumental support, informational support, emotional support, and appraisal support [36]. Norms and values that exist in *Social Support* create social influence or facilitate environments that affect the attitudes and behavioural intentions in technology acceptance [1, 37]. Based on these, the present study proposes that *Social Support* has a positive impact on *Perceived Ease of Use*, *Attitude*, and *Behavioural Intention*:

H6a *Social Support* has a positive impact on *Perceived Ease of Use* for older adults

H6b *Social Support* has a positive impact on *Attitude* for older adults

H6c *Social Support* has a positive impact on *Behavioural Intention* for older adults.

Summarizing our assumptions as described above, the extended version of TAM is regarded as a framework for our exploration of the three study questions and it furthers the hypothetical construct interrelations which are tested in our study.

4 Method

4.1 Instruments

The study consisted of two main instruments: demographics and the TAM questionnaire. For demographics, participants were asked about their gender, age, education level, economic status, living arrangement, smartphone price, and smartphone Actual Use (AU) details. These data aimed to precisely describe the sample, give a snapshot of participants' current situations, and to prepare for investigating and grading smartphone AU. From simple to complex, the function of smartphones was classified into five groups [2], namely AU 1: social and communication (e.g. making a phone call, text messaging, WeChat, or QQ), AU 2: information inquiry (e.g. mapping, reading online news, or e-learning), AU 3: entertainment (e.g. taking photos, filming videos, or playing games), AU 4: business and economy (e.g. e-payment or e-banking), AU 5: artificial intelligence operation (e.g. smart home system or health monitoring). Based on the frequency of use, each group was valued on a 5-point Likert scale ranging from 1 (*never*) to 5 (*frequently*).

Most of the adopted scales and items in the TAM questionnaire have been widely used and validated in previous empirical studies using the TAM [16, 19, 23, 38, 39]. The final version of the questionnaire comprised 27 items (Table 1) and the response to each item was measured on a 5-point Likert scale ranging from 1 (*strongly disagree*) to 5 (*strongly agree*). In order to provide an optimal range of response categories among older adults, the 5-point scale was presented by using a visual analogue format that had graphic scaling with interval values from 1 to 5 [17, 40, 41]. No open-ended questions were asked.

The language of the instrument was Chinese. In order to ensure maximum precision in the translation of items, we invited a Chinese-English translator to supervise the preparation of the instrument. We also conducted a pre-interview with

Table 1 Constructs of the instrument

Constructs	Sample of items	Source
Perceived Usefulness	Using a smartphone would make it easier to do my daily life activities	[19, 20, 23, 39]
Perceived Ease of Use	Learning to use a smartphone would be easy for me	[19, 20, 23, 39]
Attitude	Using a smartphone is a good idea	[23, 39]
Behavioural Intention	I intend to use a smartphone more in my daily life	[23, 39]
Self-efficacy	I could complete a task using a smartphone if there is someone to demonstrate how	[27, 28]
Technology Anxiety	I feel apprehensive about using a smartphone	[1, 16, 27, 28, 32]
Social Support	My family supports that I should use a smartphone	[1, 23, 28, 34, 35]

five participants to check whether the items of the instrument could be understood by older adults clearly. Some expressions were reviewed and revised according to the pre-interview results.

4.2 Data collection and participants

Data were collected through community-based surveys conducted in East China between October and December 2020. Forty-two community centres for older adults (e.g. learning centres and activity centres) were selected as the survey sites. In China, community centres are the most popular places for social activities of both urban and rural older adults. The activities in the college were organised and funded by the municipal government. Therefore, with the assistance of community centre officials and employed investigators, we collected the data when the older adults gathered there for exercise and social networking. In accordance with Chinese retirement policy (50 for female, 55 for male) and previous studies [42], the inclusion criteria for the participants were that they were over 50 years old, meanwhile, owning a smartphone or having smartphone operation experience.

Before data collection, training and instruction was provided to the investigators to familiarise them with the questionnaire and ensure standardised procedures across settings. The researchers also monitored the data collection process using random checks. The participants were asked to complete a questionnaire, and either paper or electronic forms were available. It took approximately 10 min on average to complete the questionnaire. Prior to beginning the study, ethics approval was obtained from the University Ethics Committee. Participants were informed of the objectives of the study, procedures for data collection, confidentiality, and the right to withdraw at any time and to decline to answer any of the questions.

5 Results

The study sample consisted of 1,006 participants aged over 50 years old from 42 community centres (Mean = 59.01, SD = 6.401). Nearly half were between 50 and 59 years old (57.36%), 34.39 per cent were between 60 and 69 years old, and 8.25 per cent were aged over 70. The sample comprised of 41.75 per cent males and 58.25 per cent females. Less than one tenth of the sample (8.05%) reported that they had completed primary school, more than half (67%) finished secondary school, and the rest (24.95%) had tertiary education. With reference to the subjective measure of economic status, nearly one-third (31.91%) identified themselves as ''rich'', 64.51 per cent identified themselves as "medium", and 3.58 per cent viewed themselves as "poor" More than 500 participants (53.28%) lived in urban areas, 27.04 per cent lived in suburban areas and towns, and 19.68 per cent lived in villages and in the countryside. As for the smartphone price, 47.32 per cent of them was in the range of 1001- 3000 CNY (n = 476), 47.71 per cent was above 3001 CNY (n = 480), and the last 4.97 per cent was less than 1000 CNY (n = 50). More than half of the sample lived together with two or more generations (n = 560). The average years of use was 5.17 (SD = 5.20).

5.1 Measurement Model

A confirmatory factor analysis (CFA) was conducted on the survey data using AMOS 23 to determine whether the seven-constructs measurement model fit the data well. The Kaiser–Meyer–Olkin index of the model was considered appropriate (KMO = 0.913, χ^2 = 11,618.595, DF = 351, P < 0.001). The item loadings of the seven constructs ranged from 0.638 to 0.869, which all exceeded the recommended threshold of 0.6 [43]. The reliability of the constructs (CR) was also guaranteed since the values of Cronbach's χ were all above 0.6 [44]. We checked the convergent validity and discriminant validity of the constructs by using the parameter of average variance extracted (AVE). With reference to Fornell and Larcker's criterion [45], the values of AVE were all above the minimum value of 0.5, and the correlation coefficients between two constructs were all less than the square root of each construct's AVE (Table 2). The results of CFA also reconfirmed the validity of the model. We found that the model fit our data well (χ^2 = 1167.423, DF = 303, P < 0.000, NFI = 0.901, TLI = 0.912, CFI = 0.924, RMSEA = 0.053).

Table 2 Discriminant validity check

	PU	PEOU	ATT	BI	SS	TA	SE
PU	**0.787**						
PEOU	0.691	**0.764**					
ATT	0.777	0.693	**0.806**				
BI	0.688	0.548	0.758	**0.810**			
SS	0.569	0.577	0.651	0.615	**0.758**		
TA	− 0.119	− 0.215	− 0.079	− 0.051	0.112	**0.761**	
SE	0.526	0.444	0.642	0.575	0.556	0.201	**0.798**

PU: Perceived Usefulness, *PEOU*: Perceived Ease of Use, *SE*: Self-efficacy, *ATT*: Attitude, BI: Behavioural Intention, *SS*: Social Support

Table 3 Structural model hypotheses

Construct	Path	Path coefficients	p value	Supported
H1	PU —> ATT	0.618	$p < 0.001$	Yes
H2a	PEOU —> PU	0.531	$p < 0.001$	Yes
H2b	PEOU —> ATT	0.096	0.066	No
H3	ATT —> BI	0.666	$p < 0.001$	Yes
H4a	SE —> PU	0.369	$p < 0.001$	Yes
H4b	SE —> PEOU	0.225	$p < 0.001$	Yes
H5a	TA —> PU	−0.087	0.001	Yes
H5b	TA —> PEOU	− 0.314	$p < 0.001$	Yes
H6a	SS —> PEOU	0.49	$p < 0.001$	Yes
H6b	SS —> ATT	0.28	$p < 0.001$	Yes
H6c	SS —> BI	0.182	$p < 0.001$	Yes

PU: Perceived Usefulness, *PEOU*: Perceived Ease of Use, *SE*: Self-efficacy, *ATT*: Attitude, *BI*: Behavioural Intention, *SS*: Social Support

5.2 Structural model

The structural model was tested with path coefficients (β) and significance values (p). As displayed in Table 3, hypotheses 1–3 indicated the relationships within the basic TAM and all the hypotheses were supported except for Hypothesis 2b, which predicted that Perceived Ease of Use did not have a direct impact on Attitude towards smartphone use (H2b: $\beta = 0.096$, $p = 0.066$). This result was opposed to the basic TAM proposed by Davis [19]; however, it is consistent with some prior studies which claimed that perceived ease of use had no direct impact on users' attitude towards accepting new technologies such as smart watches, e-learning systems, and desktop computers.

Hypotheses 4a and 4b dealt with the relationships between Self-efficacy and the TAM. Self-efficacy had a positive impact on both Perceived Usefulness (H4a: $\beta = 0.369$, $p < 0.001$) and Perceived Ease of Use (H4b: $\beta = 0.225$, $p < 0.001$). Hypotheses 5a and 5b were concerned with the relationships between Technology Anxiety and the TAM. Technology Anxiety had a negative impact on both Perceived Usefulness (H5a: $\beta = -0.087$, $p < 0.01$) and Perceived ease of Use (H5b: $\beta = -0.314$, $p < 0.001$). Hypotheses 6a to 6c were related to the relationships between Social Support and the TAM. Social Support had a positive impact on Perceived Ease of Use (H6a: $\beta = 0.49$, $p < 0.001$), Attitude towards use (H6b: $\beta = 0.28$, $p < 0.001$), and Behavioural Intention (H6c: $\beta = 0.182$, $p < 0.001$) (Fig. 1).

5.3 Smartphone AU levels

In the variable of smartphone AU, the majority of participants engaged "frequently" in AU 1 (87.28%), AU 2 (77.14%), AU 3 (74.35%), and AU 4 (71.07%), but less than 20 per cent engaged in AU 5 (16.51%). The proportion of participants that chose "often" ranged from 12.23 per cent (AU 1) to 35.59 per cent (AU 5). In respect to the function of AU 3, AU 4, and AU 5, 0.30 per cent, 1.59 per cent, and 16.00 per cent of participants, respectively, reported that they had "never" tried. The diagrams are illustrated in Fig. 2. Cluster analysis was a method of grouping samples, it could objectively reflect the inner syntagmatic relations [46]. Q-cluster referred to the hierarchical cluster analysis [47, 48]. In this study, after applying the Q-cluster by SPSS 23, the participants with similar engagement in smartphone AU was graded into three levels (clusters): primary level ($n = 45$, 4.47%), medium level ($n = 331$, 32.91%), and advanced level ($n = 630$, 62.62%).

One-way univariate analyses of variance (ANOVAs) were conducted to evaluate all the constructs for the three levels of smartphone use. Significant results were followed up with Tukey's post hoc group mean comparisons. The ANOVAs results indicated significant differences between the three levels in *Perceived Usefulness* ($F(2,1003) = 89.617$, $p < 0.001$, $\eta p^2 = 0.152$), *Perceived Ease of Use* ($F(2,1003) = 208.971$, $p < 0.001$, $\eta p^2 = 0.294$), *Attitude* ($F(2,1003) = 100.661$, $p < 0.001$, $\eta p^2 = 0.167$), *Behavioural Intention* ($F(2,1003) = 102.462$, $p < 0.001$, $\eta p^2 = 0.170$), *Self-efficacy* ($F(2,1003) = 28.435$, $p < 0.001$, $\eta p^2 = 0.054$), *Technology Anxiety* ($F(2,1003) = 12.958$, $p < 0.001$, $\eta p^2 = 0.025$), and *Social Support* ($F(2,1003) = 89.617$,

$p < 0.001$, $\eta p^2 = 0.152$). The results of Tukey's post hoc pairwise comparison (Table 4) indicated that, for the constructs of *Perceived Usefulness*, *Perceived Ease of Use*, *Attitude*, *Behavioural Intention*, and *Social Support*, the means of the three smartphone AU levels differed from one another significantly, and increased gradually from the primary to the advanced level. For the construct of *Self-efficacy*, the means of the levels also ranked in ascending order, but the

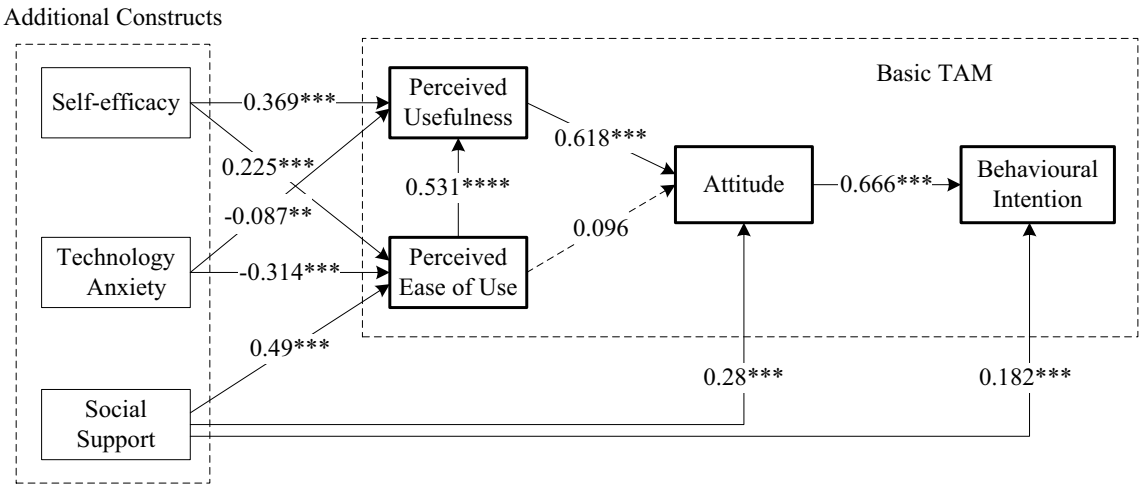

Fig. 1 The structural model. *Note*. $^{*}p < 0.05$; $^{**}p < 0.01$; $^{***}p < 0.001$

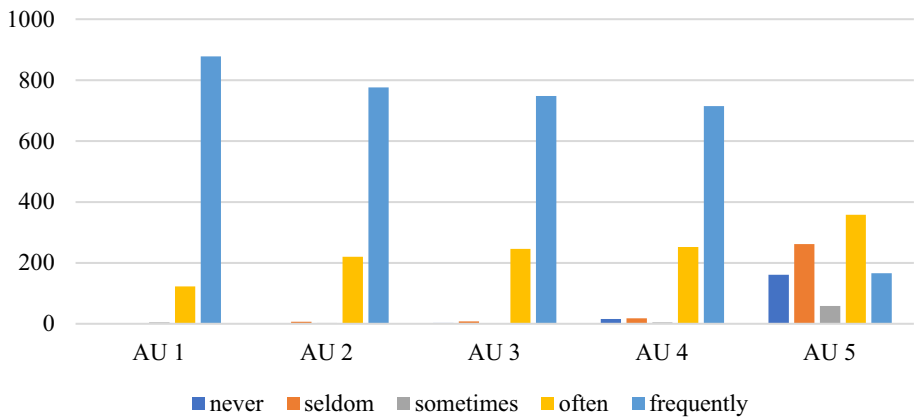

Fig. 2 An overview of the smartphone actual use in five groups

Table 4 Group means on measures of smartphone acceptance model constructs

Measure	Smartphone actual use level					
	Primary		Medium		Advanced	
	M	*SD*	*M*	*SD*	*M*	*SD*
PU	$16.56_{a,b,c}^{***}$	2.14	$18.20_{a,b,c}^{***}$	1.57	$19.19_{a,b,c}^{***}$	1.04
PEOU	$12.78_{a,b,c}^{***}$	2.78	$15.56_{a,b,c}^{***}$	2.03	$17.42_{a,b,c}^{***}$	1.67
ATT	$11.82_{a,b,c}^{***}$	2.01	$13.00_{a,b,c}^{***}$	1.42	$13.98_{a,b,c}^{***}$	1.20
BI	$12.80_{a,b,c}^{***}$	1.85	$13.93_{a,b,c}^{***}$	1.21	$14.59_{a,b,c}^{***}$	0.73
SE	16.98_{a}^{***}	2.54	17.68_{b}^{***}	2.15	$18.55_{a,b}^{***}$	1.92
TA	16.96_{a}^{*}	3.05	16.07_{b}^{***}	3.34	$14.96_{a,b}$	4.10
SS	$23.96_{a,b,c}^{***}$	3.26	$25.67_{a,b,c}^{***}$	2.42	$27.37_{a,b,c}^{***}$	2.20

Means in a row sharing subscripts (i.e. a, b, c) were found to significantly differ from each other in Tukey's post hoc mean comparisons. Larger means indicate greater levels of each respective construct. $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$. PU: Perceived Usefulness, PEOU: Perceived Ease of Use, SE: Self-efficacy, ATT: Attitude, BI: Behavioural Intention, SS: Social Support

difference between the primary and the medium level was not significant. For the construct of *Technology Anxiety*, the higher the use level, the lower the technology anxiety, but the difference between the primary and the medium level was not significant.

6 Discussion

The study proved the fitness of extended TAM in smartphone use, and calculated the effects of additional constructs (i.e. *Self-efficacy*, *Technology Anxiety*, and *Social Support*). Besides, with reference to each additional construct, the study analysed the use level differences among older adults.

Specifically, it confirmed that *Self-efficacy* positively predicted the older adults' *Perceived Usefulness* and *Perceived Ease of Use* of smartphones. This finding coincided with most of the previous studies on ICT acceptance [17, 23]. Moreover, the sense of Self-efficacy enhanced gradually with the upgrades of the use levels, and the older adults with higher self-efficacy were more likely to find smartphones useful and easy to use [49, 50]. The results also revealed that *Technology Anxiety* had a direct negative relationship with either *Perceived Usefulness* or *Perceived Ease of Use* in smartphone use. It is indisputable that older adults who were worried and apprehensive about using smartphones would find it harder to recognise their usefulness. Specifically, a sense of fear and apprehension could restrict older adults' acceptance of new technology efficiently and effectively [28]. The outcomes mentioned above highlighted the significance of emotional states, as well as the crucial value of technology anxiety in older adult's smartphone use.

The study also found that *Social Support* positively predicted older adults' Perceived Ease of Use. In the case of older adults' social network characteristics, we introduced family and peer support as constituent factors of social support and the results provide more contextual evidence that older adults who engaged in high levels of interaction with family members and peers could effectively reduce their difficulties with smartphone use. It coincided with previous studies in which the home and community were highlighted as the preferred place for ICT use and skills improvement [13, 51–55]. The availability of social support from family members, as well as peer-to-peer assistance and encouragement, could compel active engagement with new technologies [13, 56–58]. Our results specified the influential factors and proved that only the combination of family and community items could cover the factors of instrumental support, informational support, emotional support, appraisal support, and socializing [11, 36, 59], and could significantly improve the efficiency of smartphone use of older adults.

Although most of TAM related studies revealed that perceived ease of use positively predicted users' attitudes towards new technology acceptance, our results show that this relationship was not suitable for older adults. This might be because 'age-friendly' was the basic principle and premise in older adult-oriented ICT design [15, 60]. An age-friendly design was defined as one that satisfied the following objectives: (a) addressed older adults' basic needs (e.g. communication) and promoted their social engagement; (b) optimized and simplified ICT operation; and (c) maximized digital independence by providing opportunities and offering support. In China, on account of the rapid ageing, many mobile phone manufacturers had especially developed "smartphone for the older adults" (老人手机). The visual issues, haptic issues, and various elements of textual interface were all taken into account when these smartphones were designed. Specifically, the screen size should be large, the audio system should be particularly set up, and the operating system should be convenient. Moreover, there was no rigid requirement or assessment standard before and after they used the smartphones, so they could purchase and operate the smartphones within their capabilities [60]. This point of view was supported by our investigation of the five AU groups which indicated that use frequency decreased according to operation complexity.

In addition to the extended TAM model, the other two innovations were the fact that grading and grouping of older adults was based on smartphone use, and that the comparison of group differences for the seven constructs was conducted by statistical methods. One of the most noteworthy findings was that, in older adults' smartphone use, the sense of technology anxiety could not be eliminated completely but it would decrease with the use level upgrade, namely, the more skilled the older adults were, the more relaxed they could be. This finding cohered with the views that the more ICT exposure an individual had, the more comfortable she/he became and the greater likelihood for continued use [52, 57, 58]. Moreover, most previous studies were based on qualitative methods (e.g. in-depth interviews) and the grading of use levels also depended on subjective judgement [10]. Our attempt was a continuation of and complement to previous studies.

7 Conclusion and limitations

This study proposed an extended smartphone acceptance model of older adults by adding constructs of *Self-efficacy*, *Technology Anxiety*, and *Social Support*. Meanwhile, through Q-cluster analysis and ANOVAs, we graded the participants into three levels and compared their specific differences. Notably, older adult was a diverse group and did not uniformly conform to technology averse stereotypes. Digital divide and digital inequality had not prevented them

from learning and accepting new technologies, as well as new ways of life.

The study not only made a theoretical contribution to the existing literature but also has practical implications. It was consistent with the practical problems and digital ageing trends in many countries, and the findings provide a reference for future research priorities and policy decisions, such as for instance, how to create a distinct and multiple ICT training mechanism for various older adult subgroups; how to provide tailored, affordable, and encouraging training opportunities to older adults at convenient locations and preferred time; or how to facilitate the combination of intergeneration support and peer-to-peer assistance.

With the help of community centre officials and employed investigators, we removed many obstacles, but still encountered practical difficulties and limitations, such as applying the questionnaire with older adults who were unfamiliar with filling in a 5-point Likert questionnaire. Only older adults who lived in communities were included in the sample frame; there was no coverage of those who lived in villages or the countryside. Moreover, the age inclusion criterion for the participants (over 50 years old) was based on the national retirement and pension policies, and it might not be transferable to social contexts outside China.

Funding This work was supported by The National Social Science Fund of China, grant number 22CSH078; Social Science Foundation of Jiangsu Province, grant number 22SHD006; and Planning Subject for the 13th Five Year Plan of National Education Sciences, grant number DKA190449.

Availability of data and material The data set supporting the results of this work were included within the article.

Code availability Not applicable.

Declarations

Conflicts of interest The authors declare no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Consent to participate The data collected in this work had been agreed by all participants.

Consent for publication Written/online informed consent for publication was obtained from all participants.

Ethics approval Ethics Approval was obtained from the University Ethics Committee.

References

1. Jun, J.S., Galambos, C., Lee, K.H.: Information and communication technology use, social support, and life satisfaction among Korean immigrant elders. J. Soc. Service Rese. **46**, 1–16 (2020). https://doi.org/10.1080/01488376.2020.1848969
2. Choudrie, J., Pheeraphuttranghkoon, S., Davari, S.: The digital divide and older adult population adoption, use and diffusion of mobile phones: A quantitative study. Inf. Syst. Front. **22**(3), 673–695 (2020)
3. Callegaro, M., Lozar Manfreda, K., & Vehovar, V.: Web Survey Methodology. Sage (2015). ISBN 0857028618
4. Galambos, C., Skubic, M., Wang, S., Rantz, M.J.: Management of dementia and depression utilizing in home passive sensor data. Gerontechnology **11**(3), 457–468 (2013)
5. Ha, J., Park, H.K.: Factors affecting the acceptability of technology in health care among older Korean adults with multiple chronic conditions: a cross-sectional study adopting the Senior Technology Acceptance Model. Clin. Interv. Aging **15**, 1873–1881 (2020)
6. Carpenter, D.: Surfing seniors. Hosp. Health Netw. **74**(10), 26–26 (2000)
7. Pan, S.Y., Jordan-Marsh, M.: Internet use intention and adoption among Chinese older adults: From the expanded technology acceptance model perspective. Comput. Hum. Behav. **26**(5), 1111–1119 (2010)
8. China Internet Network Information Center. The 47th China Statistical Report on Internet Development, (2020). http://cnnic.cn/hlwfzyj/hlwxzbg/hlwtjbg/202102/P020210203334633480104.pdf (in Chinese)
9. Castells, M.: The Rise of the Network Society: Networks and Identity, 2nd edn. Blackwell, Oxford (2010)
10. Hardill, I., Olphert, C.W.: Staying connected: Exploring mobile phone use amongst older adults in the UK. Geoforum **43**(6), 1306–1312 (2012)
11. Petrovcic, A., Fortunati, L., Vehovar, V., Kavcic, M., Dolnicar, V.: Mobile phone communication in social support networks of older adults in Slovenia. Telematics Inform. **32**(4), 642–655 (2015)
12. Greengard, S.: Facing an age-old problem. Commun. ACM **52**(9), 20–22 (2009)
13. Fang, M. L., Canham, S. L., Battersby, L., Sixsmith, J., Wada, M., & Sixsmith, A.: Exploring Privilege in the Digital Divide: Implications for Theory, Policy, and Practice. Gerontologist **59**(1), 1–15(2019) https://academic.oup.com/gerontologist/article/59/1/e1/4994703
14. Tsai, H. Y. S., Shillair, R., Cotten, S. R., Winstead, V., & Yost, E. (2015) Getting grandma online: Are tablets the answer for increasing digital inclusion for older adults in the U.S. Educational Gerontology **41**(10), 695–709
15. Barnard, Y., Bradley, M.D., Hodgson, F., Lloyd, A.D.: Learning to use new technologies by older adults: Perceived difficulties, experimentation behaviour and usability. Comput. Hum. Behav. **29**(4), 1715–1724 (2013)
16. Hacer, G., Acarturk, C.: The use and acceptance of ICT by senior citizens: A comparison of Technology Acceptance Model (TAM) for elderly and young adults. Univ. Access Inf. Soc. **19**(02), 311–330 (2020)
17. Chen, K., Chan, A.H.S.: Gerontechnology acceptance by elderly Hong Kong Chinese: A senior technology acceptance model (STAM). Ergonomics **57**(5), 635–652 (2014)
18. Marangunic, N., Granic, A.: Technology acceptance model: A literature review from 1986 to 2013. Univ. Access Inf. Soc. **14**(1), 81–95 (2015)
19. Davis, F.D.: Perceived usefulness, perceived ease of use, and user acceptance of information technology. MIS Q. **13**(3), 319–340 (1989)
20. Davis, F.D., Bagozzi, R.P., Warshaw, P.R.: User acceptance of computer technology – A comparison of 2 theoretical models. Manage. Sci. **35**(8), 982–1003 (1989)

21. Fishbein, M., & Ajzen, I.: Belief, attitude, intention and behaviour: An introduction to theory and research. Addison-Wesley (1975). ISBN 9780201020892
22. Ajzen, I.: The theory of planned behavior. Organ. Behav. Hum. Decis. Process. **50**(2), 179–211 (1991)
23. Venkatesh, V., Morris, M.G., Davis, G.B., Davis, F.D.: User acceptance of information technology: Toward a unified view. MIS Q. **27**(3), 425–478 (2003)
24. Dogruel, L., Joeckel, S., Bowman, N.D.: The use and acceptance of new media entertainment technology by elderly users: Development of an expanded technology acceptance model. Behaviour & Information Technology **34**(11), 1052–1063 (2015)
25. Bandura, A.: Self-efficacy: The exercise of control. W. H. Freeman and company (1997). ISBN 9780716728504
26. Straub, E.T.: Understanding technology adoption: Theory and future directions for informal learning. Rev. Educ. Res. **79**(2), 625–649 (2009)
27. Abdullah, F., Ward, R.: Developing a General Extended Technology Acceptance Model for E-Learning (GETAMEL) by analysing commonly used external factors. Comput. Hum. Behav. **56**, 238–256 (2016)
28. Zheng, J., Li, S.: What drives students' intention to use tablet computers: An extended technology acceptance model. Int. J. Educ. Res. **102**, 101612 (2020)
29. Oyedele, A., Simpson, P.M.: An empirical investigation of consumer control factors on intention to use selected self-service technologies. Int. J. Serv. Ind. Manag. **18**(3), 287–306 (2007)
30. Cambre, M.A., Cook, D.L.: Computer anxiety: Definition, measurement, and correlates. Journal of Educational Computing Research **1**(1), 37–54 (1985)
31. Meuter, M.L., Ostrom, A.L., Bitner, M.J., Roundtree, R.: The influence of technology anxiety on consumer use and experiences with self-service technologies. J. Bus. Res. **56**(11), 899–906 (2003)
32. Tsai, T.H., Lin, W.Y., Chang, Y.S., Chang, P.C., Lee, M.Y.: Technology anxiety and resistance to change behavioural study of a wearable cardiac warming system using an extended TAM for older adults. PLoS ONE **15**(1), 1–24 (2020)
33. Cohen, S.: Social relationships and health. Am. Psychol. **59**(8), 676–684 (2004)
34. Mori, K., Harada, E.T.: Is learning a family matter? Experimental study of the influence of social environment on learning by older adults in the use of mobile phones. Jpn. Psychol. Res. **52**(3), 244–255 (2010)
35. Tsai, H.Y.S., Rikard, R.V., Cotten, S.R., Shillair, R.: Senior technology exploration, learning, and acceptance (STELA) model: From exploration to use - a longitudinal randomized controlled trial. Educ. Gerontol. **45**(12), 728–743 (2019)
36. House, J. S.: Work stress and social support. Addison-Wesley (1981). ISBN 0201031019
37. Ashida, S., Heaney, C.A.: Differential associations of social support and social connectedness with structural features of social networks and the health status of older adults. J. Aging Health **20**(7), 872–893 (2008)
38. Park, J., Han, S.H., Kim, H.K., Cho, Y., Park, W.: Developing elements of user experience for mobile phones and services: Survey, interview, and observation approaches. Human Factors Ergonomics in Manufacturing & Service Industries **23**(4), 279–293 (2013)
39. Venkatesh, V., Davis, F.D.: A theoretical extension of the technology acceptance model: Four longitudinal field studies. Manage. Sci. **46**(2), 186–204 (2000)
40. Castle, N.G., Engberg, J.: Response formats and satisfaction surveys for elders. Gerontologist **44**(3), 358–367 (2004)
41. Wee, H.L., Fong, K.Y., Tse, C., Machin, D., Cheung, Y.B., Luo, N., Thumboo, J.: Optimizing the design of visual analogue scales for assessing quality of life: A semi-qualitative study among Chinese-speaking Singaporeans. J. Eval. Clin. Pract. **14**(1), 121–125 (2008)
42. Cambridge dictionary.: Meaning of silver surfer in English. https://dictionary.cambridge.org/us/dictionary/english/silver-surfer
43. Pituch K. A. & Stevens, J. P.: Applied multivariate statistics for the social sciences (6th ed.). Routledge (2016). ISBN 13:9781315814919
44. Hair, J. F., Black, W. C., Babin, B. J., & Anderson, R. E.: Multivariate data analysis (6th ed.) Prentice Hall (2009). ISBN 9780138132637
45. Fornell, C., Larcker, D.F.: Evaluating structural equation models with unobservable variables and measurements error: algebra and statistics. J. Mark. Res. **18**(4), 39–50 (1981)
46. Macgill, S.: Cluster analysis and Q-analysis. Int. J. Man Mach. Stud. **20**, 595–604 (1984)
47. Gould, P.: Q-analysis, or a language of structure: an introduction for social scientists, geographers and planners. Int. J. Man Mach. Stud. **13**, 169–199 (1980)
48. Zhi, C.: Methods of factor analysis and cluster analysis by SPSS. Mark. Res. **6**, 45–48 (2006). ((**in Chinese**))
49. Hickman, J.M., Rogers, W.A., Fisk, A.D.: Training older adults to use new technology. J. Gerontol. Series B-Psychological Sci. Social Sciences **62**, 77–84 (2007)
50. Scott, J.E., Walczak, S.: Cognitive engagement with a multimedia ERP training tool: Assessing computer self-efficacy and technology acceptance. Information & Management **46**(4), 221–232 (2009)
51. Atkinson, J., Black, R., Curtis, A.: Exploring the digital divide in an Australian regional city: A case study of Albury. Aust. Geogr. **39**(4), 479–493 (2008)
52. Chang, J., McAllister, C., McCaslin, R.: Correlates of, and barriers to, Internet use among older adults. J. Gerontol. Soc. Work **58**(1), 66–85 (2015)
53. Lang, F.R., Carstensen, L.L.: Close emotional relationships in late life – Further support for proactive aging in the social domain. Psychol. Aging **9**(2), 315–324 (1994)
54. Shaw, B.A., Krause, N., Liang, J., Bennett, J.: Tracking changes in social relations throughout late life. Journals of Gerontology Series B-Psychological Sciences and Social Sciences **62**(2), S90–S99 (2007)
55. Arthanat, S., Vroman, K.G., Lysack, C.: A home-based individualized information communication technology training program for older adults: a demonstration of effectiveness and value. Disability And Rehabilitation-Assistive Technology **11**(4), 316–324 (2016)
56. Arthanat, S., Vroman, K.G., Lysack, C., Grizzetti, J.: Multi-stakeholder perspectives on information communication technology training for older adults: implications for teaching and learning. Disability And Rehabilitation-Assistive Technology **14**(5), 453–461 (2019)
57. Larsson, E., Larsson-Lund, M., Nilsson, I.: Internet based activities (IBAs): Seniors' experiences of the conditions required for the performance of and the influence of these conditions on their own participation in society. Educ. Gerontol. **39**(3), 155–167 (2013)
58. Friemel, T.N.T.N.: The digital divide has grown old: Determinants of a digital divide among seniors. New Media Soc. **18**(2), 313–331 (2016)
59. Gurung, R.A.R., Taylor, S.E., Seeman, T.E.: Accounting for changes in social support among married older adults: Insights from the MacArthur studies of successful aging. Psychol. Aging **18**(3), 487–496 (2003)

60. Petrovcic, A., Taipale, S., Rogelj, A., Dolnicar, V.: Design of mobile phones for older adults: an empirical analysis of design guidelines and checklists for feature phones and smartphones. Inter. J. Human-Comput. Interaction **34**(3), 251–264 (2018)