Innovation and Development Policy

Available online at http://idp-journal.casisd.cn/

Research on the Influencing Factors of Gerontechnology Acceptance by Seniors: A Case Study of Beijing Elderly Citizens

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Abstract

Based on the framework of social cognition theory, this paper proposed a systematic gerontechnology acceptance model for older people from both environmental and personal factors. Taking the Beijing senior citizens as an example, we used questionnaire survey data analysis and structural equation modeling methods to conduct empirical research that explores the factors affecting the willingness of the Beijing senior citizens to use gerontechnology and to examine the relationships among these factors. Results show that – in terms of personal factors – self-satisfaction, perceived usefulness and cognitive ability have a significant positive impact on the elderly's intended uptake of gerontechnology; in terms of environmental factors, social influence not only directly affects the elderly's intended use, but these elements can also shape the proposed use by influencing personal factors. We noted that facilitating conditions have only an indirect effect on the way of older people's plan to use gerontechnology. The results confirmed the rationality and effectiveness of applying social cognition theory to study the behavior of seniors' acceptance of gerontechnology. Based on the research results, we proposed some suggestions to promote better research and development of gerontechnology for the elderly in Beijing.

Keywords

Social Cognitive Theory; gerontechnology; technology acceptance model; seniors

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https://doi.org/10.3724/SP.J.2096-5141.2021.0006

1. Introduction

According to the "Medium and Long-term Plan for the State to Actively Respond to Population Aging"[1] issued by the State Council of China in November 2019, the number of seniors aged 60 and over in China increased from 126 million to 249 million in the period 2010 to 2018, and the proportion in the total population rose from 10.2% to 17.9%. Judging from the current trend, China's aging population will continue to rise at a relatively steep gradient. In the next five years, China might become a moderately aging society. After 2030, the population aged 65 and over will exceed 20%, and China will enter a rapidly aging society, indicating the country's aging population could well become a very serious concern[2]. The government sees the rapid development of China's aging population as a critical challenge. In November 2019, the State Council of China proposed to implement the innovation-driven development strategy in depth and give full play to the leading role of technological innovation that responds directly to the aging population. Through technological innovation, we can provide the products needed by seniors for meeting their needs effectively. At the same time, the situation calls for a vigorous development of the gerontechnology industry – technological innovation for the aging society – thereby forming a new economic growth point and providing a sufficient material basis in response. The premise of actively countering population aging with technological innovation involves identifying factors that influence the acceptance of gerontechnology by seniors. This is particularly significant in the context of the rapid development of intelligent technology alongside an aging population. As primary audiences in the future market, it is exceptionally important to analyze factors that influence seniors' acceptance and use of gerontechnology.

Gerontechnology is defined as electronic or digital products or services that can increase independent living and social participation of older persons in relatively good health, comfort and safety (Chen and Chan, 2014), such as intelligent walking sticks, elderly medical monitoring devices, elderly educational or hands-on toys. The market response shows that the acceptance of gerontechnology by seniors is a complex problem with many influencing factors, and is not limited to the performance and price of gerontechnology. We note that various elements have combined to create the "digital divide" among seniors. At present, the research on the factors affecting the acceptance of gerontechnology by seniors is relatively limited, and usually focuses on gerontechnology or services in specific areas, such as Internet use (Lan and Lu, 2019) and related social network services, such as online shopping (Lian and Yen, 2014), mobile health services (Deng *et al*., 2014; Mo and Deng, 2015; Hoque and Sorwar, 2017), home telemedicine services (Cimperman *et al*., 2016), smart phones (Ma *et al*., 2016), information communication technologies (Macedo *et al*., 2017), and visualization technologies (Fernández *et al*., 2017). The research results obtained for these specific gerontechnology routines are not universal, and whether they can be extrapolated to general conclusions is still a question worth exploring. Li *et al*. (2017) and Chen *et al*. (2014) used the Unified Theory of Acceptance and Use of Technology (UTAUT) model and the Technology Acceptance Model (TAM) to study the factors affecting the acceptance behavior of multiple types of gerontechnology by elderly Hong Kong Chinese. The current research results provide the foundation for this paper, but there is also some room for improvement. First, there is a lack of analysis of the relationship between the various factors influencing

[1] http://www.gov.cn/zhengce/2019-11/23/content_5454778.htm
[2] https://www.sohu.com/a/434210834_222256

seniors' acceptance and usage of gerontechnology. In fact, not only will each factor have a singular impact on seniors' acceptance and usage of gerontechnology, but also whether or not the interaction of various factors will affect the seniors' acceptance and usage of gerontechnology remains an important research question. Second, most of the current researches on seniors' acceptance of gerontechnology involve a simple combination of basic technology acceptance models (TAM and UTAUT) (Pan and Jordan, 2010; Chen and Chan, 2014); or they explain the model by introducing new variables on the grounds of the basic technology acceptance model that meets research needs (Deng *et al*., 2014; Mo and Deng, 2015; Hoque and Sorwar, 2017; Cimperman *et al*., 2016; Ma *et al*., 2016; Macedo *et al*., 2017; Li *et al*., 2017; Chen and Chan, 2014). However, these researches do not consider classifying variables from the perspective of systems, thereby neglecting theories of marketing and social psychology (Golant, 2017). Therefore, research in this field should strengthen the theoretical basis and systematism.

Therefore, in this paper, we summarized and classified the factors that influence seniors' acceptance and employment of gerontechnology, and proposed a systematic gerontechnology acceptance model for elderly person. In addition, this study considers the fact that China's gerontechnology industry for the elderly is still in its infancy, and that scholars have done scant research on the factors affecting the elderly's acceptance and application of gerontechnology (Zhang and Song, 2015). As inhabitants of the capital of China, Beijing elderly citizens have a relatively high level of education, and the population also provides a representative elderly group in China. Thus, this paper will take the Beijing elderly citizens as an example to verify the feasibility and effectiveness of the proposed model. Through research on the factors affecting the acceptance and usage of gerontechnology by the Beijing elderly citizens, we will explore the factors and behavioral characteristics that affect the willingness of older people to use gerontechnology, our goal being to provide some suggestions to promote the research and development of gerontechnology matching old population in Beijing.

The rest of this paper is organized as follows. Section 2 presents the theoretical basis and research hypothesis. Section 3 provides the research design. Section 4 analyzes the hypothesis test and results. Section 5 discuses and concludes the paper.

2. Theoretical Basis and Research Hypothesis

2.1. Theoretical basis and conceptual model

The Social Cognitive Theory proposed by famous psychologist Bandura considered that individual behavior is affected not only by personal factors such as cognition and personality, but also by external environmental factors such as social pressure or unique situational characteristics (Higgins, 1995). Its core view is the "triadic reciprocal determinism" model of individual behavior (Fig. 1). That is, human cognitive factors and their interaction with the environment and their behaviors are a dialectical and complete unified system (Bandura, 1986). The interaction between people and behavior reflects these subject factors such as individual cognition, thinking, and emotion affect, or determines their behavior mode (L1), and the internal feedback and external results generated by behaviors in turn partially determine the individual's thoughts, beliefs and emotional responses (L2). In the interaction between behavior and environment, although environmental conditions as the object of behavior or realistic conditions determine the direction and intensity of behavior (L3), behavior also affects or changes the environment to meet human needs (L4). The interaction between people and the environment shows that people's consciousness and cognition are not immutable but are influenced by the environment (L5).

However, the existence and function of the environment are not absolute, but potential, and depend on the subject's cognitive grasp (L6) (Zhu *et al*., 2010).

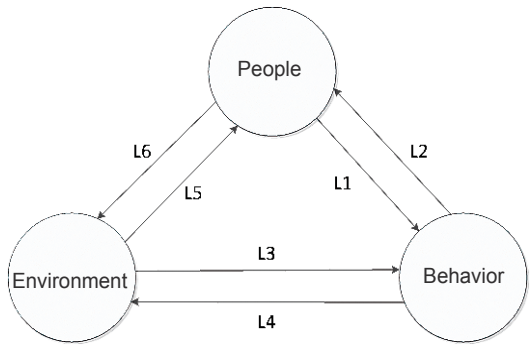

Fig. 1 The triadic reciprocal determinism model of social cognitive theory (Higgins, 1995)

A conceptual model can be constructed by applying the model of Social Cognitive Theory to analyze the intended behavior of seniors in the use of gerontechnology. In Fig. 1, human cognition, thinking, and emotion determine their behaviors. This view can be used to study seniors' attitude to use gerontechnology. So, L1 is considered. L2 means that, after the use of gerontechnology, the performance of the technology will in turn affect (strengthen or weaken) the cognition or judgment of seniors. This is a "second purchase" problem, and not the focus of this paper. Thus, L2 is not considered. The environment affects behavior. Similarly, the environment also affects seniors' envisioned application of gerontechnology, meaning L3 is considered. L4 indicates that the problems encountered by seniors in using gerontechnology can change the environment to better meet their needs, which, again, is not the purpose of this paper. So, L4 is not considered. Human cognition, thinking and emotions are affected by the environment. Considering the particularity of seniors, the environment will definitely affect their cognition and awareness of accepting gerontechnology. Therefore, L5 is taken into account. L6 represents the impact of humans on the environment, but it is not the research content of this paper, which means L6 is not part of our study. Based on the above discussion, the theoretical model in Fig. 1 is transformed into Fig. 2, and the gerontechnology acceptance model for seniors in this paper is obtained.

According to the conceptual model of seniors accepting gerontechnology, this paper will introduce the relevant theoretical basis and research results to form a hypothesis addressing the relationship between variables while exploring how environmental and personal factors affect seniors' decisions to use gerontechnology.

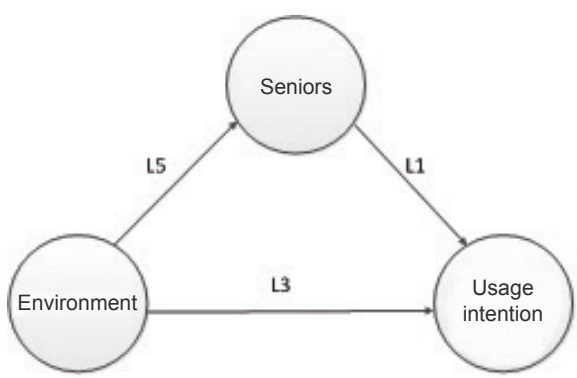

Fig. 2 Conceptual model of seniors accepting gerontechnology

2.2. Research hypothesis

2.2.1. Hypotheses based on personal factors

According to the references (Ma *et al*., 2016; Chen and Chan, 2014; Davis *et al*., 1989; Venkatesh *et al*., 2003; Lin and Guo, 2016), the personal elements of seniors in this paper include the self-perception factors of gerontechnology, namely self-satisfaction (SS), technology self-efficacy (SE), technology anxiety (ANX), perceived usefulness (PU), perceived ease of use (PEOU), and the physical factors of the elderly, in other words, cognitive ability (CA).

Self-satisfaction refers to the degree to which a product or service makes users feel satisfied with their achievements. For example, a new technology that requires users to make considerable efforts to learn can generate greater learning motivation through self-satisfaction. The belief in one's own abilities reflected in the acceptance and use of gerontechnology can be enhanced through self-satisfaction (Park *et al*., 2013). The sense of achievement generated by successfully learning to use a certain gerontechnology often motivates people to "challenge" themselves by undertaking more difficult gerontechnology which, in turn, will enhance their willingness to accept innovative products or services. In China, seniors are stronger than young people in terms of personal self-esteem and satisfaction in related life areas (Zhang and Leung, 2002). Therefore, it is of great practical significance to explore the influence of self-satisfaction on seniors' goals in using gerontechnology. It follows that the hypotheses below can be proposed.

H1: Self-satisfaction positively affects seniors' intention to make use of gerontechnology.

Technology self-efficacy refers to the personal ability to successfully use gerontechnology (Venkatesh *et al*., 2003). Some studies in recent years have found that self-efficacy is positively correlated with the use of information technology (Chen and Chan, 2014; Scott and Walczak, 2009; Lagana, 2008). Hawthorn *et al*. (2007) found that the main problem for seniors in learning to use computers is that they feel they lack the necessary ability. They claimed that they have too little knowledge and are too old to use computers, and think that the learning involved is meaningless. Technology anxiety refers to the anxiety or fear that individuals might have when using gerontechnology (Venkatesh *et al*., 2003), especially when seniors use gerontechnology alone. In this case, they often worry about danger or product damage due to incorrect operation, and even some privacy-related products appear to them to have the risk of leaking personal information. Such worries usually affect the technology usage behavior of seniors (Or *et al*., 2011; Duyck *et al*., 2008). Therefore, the following hypotheses are proposed.

H2: Technology self-efficacy positively affects seniors' decided use of gerontechnology;

H3: Technology anxiety negatively affects the way seniors feel about using gerontechnology.

According to TAM, the two most important factors that explain the acceptance and usage of information systems are how both usefulness and ease of use are perceived. Perceived usefulness refers to the degree to which individuals believe that using technology will improve their quality of life. Perceived ease of use denotes the extent to which individuals think that using technology is effortless (Davis *et al*., 1989). These two factors are critical in influencing the likelihood of seniors to accept gerontechnology (Pan and Jordan, 2010; Braun, 2013; Taiwo and Downe, 2013; Kim and Park, 2012). The research of Mitzner *et al*. (2010) and Steele *et al*. (2009) indicated that seniors are not interested in innovative gerontechnology and services themselves but attach importance to a technology that could make their daily lives easier and provide increased safety and security. In UTAUT, expectations of performance and efforts adapted from perceived usefulness and perceived ease of use have also been shown to have a significant impact on the planned use of gerontechnology (Pai and Huang, 2010; Carlsson, 2006). Especially in the initial use of technology (such as accepting innovation), the ease of use associated with it strongly affects the individual's acceptance behavior. Therefore, perceived ease of use is considered to have an increasingly

stronger ability to predict the prospects of usage (Or *et al*., 2011; Kim and Park, 2012; Kijsanayotin *et al*., 2009; Arning and Ziefle, 2009; Sun, 2013). Some studies (Pan and Jordan, 2010; Karahanna, 1999) showed that perceptions of these two elements have different effects before and after the use of gerontechnology. Therefore, it is necessary to further verify the influence of these two factors on the probability of seniors' uptake of gerontechnology. In this light, the following hypotheses are proposed.

H4: Perceived usefulness positively affects seniors' likelihood of using gerontechnology;

H5: Perceived ease of use positively affects seniors' intended use of gerontechnology.

Good cognitive ability is an important prerequisite for people in accepting something new. At the same time, acquiring new skills is essential to undertaking new things. As the cognitive ability of seniors declines with age, the decline in selective attention and working memory can make understanding and learning more difficult, and the speed of acquiring new skills is slower than that of young people (Lim, 2010; Lesch *et al*., 2011; Gong, 2015). This will directly affect the seniors' judgment and decision making on accepting new things, thereby affecting their commitment to using gerontechnology. Therefore, the following hypothesis is proposed.

H6: Cognitive ability positively affects the intention of seniors' use of gerontechnology.

2.2.2. Hypotheses based on environmental factors

Since people always live under certain social conditions, Bandura advocated studying human behavior in a natural social context rather than in a laboratory (Bandura, 1986). According to some scholars (Lian and Yen, 2014; Hoque and Sorwar, 2017; Cimperman, 2016; Macedo, 2017; Venkatesh, 2003), we have researched using the UTAUT model and its extended model research, and determined that the environmental factors to be considered in this paper are Social Influence (SI) and Facilitating Conditions (FC). We then analyzed the impact of environmental factors on seniors' personal factors and the likelihood of their use of gerontechnology.

Social influence refers to the degree to which an individual believes that he/she should use a certain product or service, which is an external condition and objective factor affecting technology acceptance (Venkatesh, 2003). The life of an individual cannot be separated from the community groups to which she/he belongs. The perceived attitude of other members of the community groups will have a direct or indirect impact on the individual, especially when exposed to new things, due to the lack of understanding of its possible performance and potential risks. In addition, direct perception experience is also relatively limited. So, it is often necessary to refer to the opinions and attitudes of others, a factor that will greatly affect the individual's cognition (Yang *et al*., 2012). If all members of the community groups are using the new technology product, it will often make people feel that the product is useful, easy to learn, and low-risk. In China, this phenomenon of "repeat word-for-word what others say" is even more obvious. Nysveen *et al*. (2005) pointed out that, when using a mobile service in the public environment, people must first observe the behavior of others and be influenced by them. This is a manifestation of "following the trends", and individuals are likely to have a sense of satisfaction and achievement of "keeping pace with the times" through "following the trends".

Due to their particularity, the self-esteem of seniors is stronger than that of the young (Zhang and Leung, 2002) and, at the same time, they are susceptible to interference and influence from others when deciding whether to accept new things. Therefore, it is necessary to explore thoroughly the impact of social influence on the personal factors of seniors. Consequently, the following hypotheses are proposed.

H7.1: Social influence positively affects the self-satisfaction of seniors;

H7.2: Social influence positively affects the technical self-efficacy of seniors;

H7.3: Social influence negatively affects the technical anxiety of seniors;

H7.4: Social influence positively affects the perceived usefulness of seniors;

H7.5: Social influence positively affects the perceived ease of use of seniors;

H7.6: Social influence positively affects the cognitive ability of seniors;

H7.7: Social influence positively affects seniors' usage intention of gerontechnology.

Facilitating conditions refer to the degree to which individuals believe that technology and infrastructure exist to support the use of a certain product, and is the perception of objective factors in the product usage environment (Venkatesh, 2003). Pan et al. (2010) found that facilitating conditions, including access channels, technical support, and product availability significantly predicted the Internet usage of the Chinese older people. Ryu et al. (2009) indicated that "perceived user resources" involving leisure time, basic knowledge, software and hardware capabilities, financial resources, and technical support are related to seniors' perceived usefulness, perceived ease of use, and the intention to participate in the creation of content services by users. In addition to the user's personal intention to use gerontechnology, most non-professionals and novices hope to have professional guidance or training courses to help them familiarize themselves with new technologies as quickly as possible. When users find that they are capable of handling new gerontechnology or can get corresponding help in the process of using them, they will be more likely to accept the new technology. For seniors, the acquisition and availability of information and communication technology support significantly increase their behavioral intentions (Or *et al*., 2011; Kijsanayotin *et al*., 2009; Heinz *et al*., 2013). At the same time, better support and training can improve seniors' satisfaction with themselves and boost their self-confidence while reducing technical anxiety (Wagner *et al*., 2010). Nevertheless, the conclusions obtained by some studies (Hoque and Sorwar, 2017; Macedo, 2017) still show that facilitating conditions are unstable in predicting the behavior of seniors in accepting gerontechnology. Consequently, it is necessary to further investigate the effects of facilitating conditions. Therefore, the following hypotheses are proposed.

H8.1: Facilitating conditions positively affect the self-satisfaction of seniors;

H8.2: Facilitating conditions positively affect the technical self-efficacy of seniors;

H8.3: Facilitating conditions negatively affect the technical anxiety of seniors;

H8.4: Facilitating conditions positively affect the perceived usefulness for seniors;

H8.5: Facilitating conditions positively affect the perceived ease of use for seniors;

H8.6: Facilitating conditions positively affect the cognitive ability of seniors;

H8.7: Facilitating conditions positively affect seniors' envisioned use of gerontechnology.

Finally, the gerontechnology acceptance model for seniors can be obtained as shown in Fig. 3.

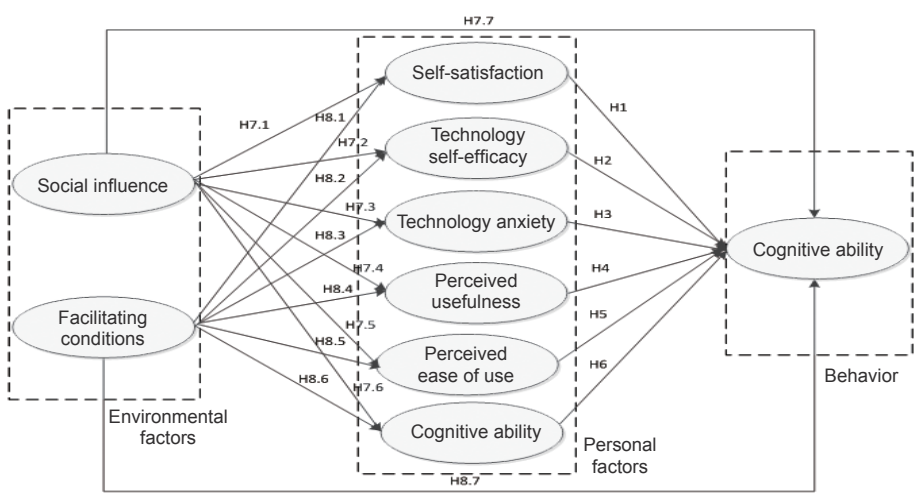

Fig. 3 The gerontechnology acceptance model for seniors

3. Research Design

3.1. Data sources and data samples

The data of this paper was obtained in the form of a questionnaire survey. The survey objects are Chinese elderly citizens living in Beijing who are over 55 years of age, including not only retirees, but also those who are about to retire. The reason why it includes the people who are going to retire is to better reflect the factors that affect the intention to use gerontechnology among the "future elder people" of China. According to the "Report on the Development of Beijing's Elderly Career and Elderly Services (2016–2017)", as of the end of 2016, there were approximately 3.292 million people aged 60 and over in Beijing, accounting for 24.1% of the total registered population. Its aging population ranks second among cities in China. At the same time, Beijing is a city with a fully developed economy and accompanying technology. Therefore, we will study the factors that affect the proposed uptake of gerontechnology among Beijing's elderly people. The results of this study will have a certain guiding significance for China's other large and medium-sized cities concerning coping with the population aging in tandem with scientific and technological innovation.

The gerontechnology in this paper refers to the relatively healthy, comfortable and safe products that can increase the independence of life and the social participation of seniors. Taking account of the similarity of the purpose of use or the environment, gerontechnology is divided into the following five categories. (1) Home and daily life groupings, such as home early warning systems, intelligent robots, and indoor action monitoring systems. (2) Information communication, such as smart phones, computers, and smart watches. (3) Health care, such as medical monitoring devices, physiotherapy devices, and remote care and medical equipment. (4) Learning and entertainment, such as mobile games, e-readers, elderly educational or hands-on toys. (5) Mobile transportation, such as intelligent walking sticks, walkers, and barrier-free handrails.

The questionnaire went through three stages, including preliminary drafting, pre-testing and formal configuration. First, in line with the research subjects, the initial questionnaire was designed on the basis of a large number of literature analyses, expert opinion summary, and modification in this field. Then we selected the elderly living in the senior centers near the Beijing University of Technology for pre-testing and then we analyzed the feedback. The final questionnaire was formed after several rounds of revision and review, made up of three main parts, comprising basic information of seniors, physical condition and their focus on using gerontechnology, and their self-perception. Considering the limitations of the seniors' comprehension and vision, the questionnaire was filled out in a "one-question-one-answer" style, using face-to-face interview. Each interview lasted about 30~60 minutes, and the questionnaire was retrieved on the spot. A total of 558 questionnaires were sent out, and 538 valid questionnaires were recovered. The effective response rate was 96%. The demographic information of the respondents is shown in Table 1.

3.2. Measurement and sources of variables

In order to ensure the reliability and validity of the questionnaire, the measurement scale draws predominantly on the measurement standards commonly used in relevant literature, with some of the topics having been revised according to the research content of this paper (as shown in Table 2). Specifically, intended use, perceived usefulness, and perceived ease of use were adjusted according to the research on TAM model by Davis *et al*. (1989). Among them, perceived usefulness was measured by three items, and usage intention and perceived ease of use were measured by two. Self-satisfaction

Table 1 Demographic information of respondents

	Items	Number of people	Percentage (%)
Gender	Male	272	50.56
	Female	266	49.44
Age	55~59	149	27.70
	60~64	121	22.49
	65~69	72	13.38
	70~74	76	14.13
	≥75	120	22.30
Living condition	Living with family	432	80.30
	Living with friends	5	0.93
	Living alone	88	16.36
	Living in an old-age care institution	7	1.30
	Others	6	1.12
Education level	Junior college education or below	318	59.11
	Undergraduate	174	32.34
	Master	22	4.09
	Doctor and above	24	4.46
Main sources of income	Salary and allowance	129	23.98
	Property income (*e.g.* financial management, rent)	9	1.67
	Pension	377	70.07
	Family funding and support	14	2.60
	Local government/agency subsidies	5	0.93
	Others	4	0.74
Average monthly income (RMB)	<3000	87	16.17
	3000-6000	231	42.94
	6000-9000	170	31.60
	>9000	50	9.29

was adapted from the research of Park *et al*. (2013) and measured by three elements. The measures of technical self-efficacy, technical anxiety, facilitating conditions, and social impact were all adapted from the research on UTAUT by Venkatesh *et al*. (2003). Technical self-efficacy was measured by 2 items, while technical anxiety, facilitating conditions, and social influence were measured by 3. The measurement of cognitive ability draws on the Chinese version of the World Health Organization Quality of Life Scale (WHOQOL-100) and its abbreviated version (WHOQOL-BREF) (Mcdowell, 2006), the effectiveness of this method has been verified in Hong Kong (Chen and Chan, 2014; Wong, 2005), and measured by 3 elements. Except for demographic variables, other measurement items were measured by a Likert 5-scale: 1-5 means “strongly disagree” - “strongly agree”.

Table 2 Variables measure items and sources

	Variables	Measurement items	References
Behaviors	Usage intention	You plan to use gerontechnology in your life	Davis *et al*., 1989
		You will often use gerontechnology in your life	
Personal factors	Perceived usefulness	Using gerontechnology will improve your quality of life	Davis *et al*., 1989
		Using gerontechnology will make your life more convenient	
		Gerontechnology are very helpful in your life	
	Perceived ease of use	Do you think it's easy to use gerontechnology	Davis *et al*., 1989
		Do you think you can use gerontechnology proficiently	
	Self-satisfaction	Using technology can make you feel or look younger	Park *et al*., 2013
		Using gerontechnology can help you keep pace with the times	
		Using gerontechnology can increase your sense of accomplishment	
	Technology self-efficacy	You can use gerontechnology with help	Venkatesh *et al*., 2003
		You can use gerontechnology through self-study	
	Technology anxiety	You are worried about the dangers of using gerontechnology	Venkatesh *et al*., 2003
		You are worried that using gerontechnology will reveal your privacy	
		You are worried that using gerontechnology will develop a sense of dependence	
	Cognitive ability	You have a good memory	Chen and Chan, 2014; Mcdowell, 2006; Wong, 2005
		You can always concentrate on things	
		You are satisfied with your ability to make decisions	
Environmental factors	Facilitating conditions	You have the knowledge required to use gerontechnology	Venkatesh *et al*., 2003
		Someone or a group will help you solve the problems encountered when using gerontechnology	
		You can use it whenever you want or need gerontechnology	
	Social influence	Surrounding peers are using gerontechnology	Venkatesh *et al*., 2003
		Family and friends think using gerontechnology is useful	
		Family and friends recommend that you use gerontechnology	

4. Hypothesis Test and Result Analysis

4.1. Reliability and validity test

Before testing the model, the reliability and validity of the scale were trialed. According to the reliability of the Cronbach'α coefficient measurement scale, the Cronbach'α coefficient values of assorted variables calculated by SPSS 19.0 were greater than 0.7 at the 0.01 significance level (as shown in Table 3).

This illustrates that the measurement content has solid internal consistency and high reliability.

The validity analysis of the scale usually includes content validity and construct validity. Since the variables of this questionnaire were based on literature that allowed us to select the high reliability and validity measurement indicators that were formed after expert discussion and modification, the results have good content validity. Construct validity was tested by confirmatory factor analysis (CFA), including convergent validity and discriminant validity. The load value of the standardization factor of each observation variable was greater than the recommended value 0.6, which means that each measurement item can be considered to converge to its corresponding latent variable. The composite reliability (CR) and average variances extracted (AVE) were used to test convergence validity (Fornell and Larcker, 1981). The CR value of each latent variable was greater than 0.6, indicating that each variable has good internal consistency. The AVE value was greater than the acceptable value 0.5, indicating that the percentage of variation that a latent variable can relate to the index exceeds 50%, which indicates that the measurement model has good reliability and convergent validity (Hair *et al*., 1995).

Table 3 Reliability and validity test of scale

	Variables	Measurement items	Standardization factor load value	CR	AVE
Behaviors (Cronbach's α=0.735)	Usage intention	UI1	0.708	0.727	0.572
		UI2	0.802		
Personal factors (Cronbach's α=0.816)	Perceived usefulness	PU1	0.884	0.911	0.773
		PU2	0.895		
		PU3	0.858		
	Perceived ease of use	PEOU1	0.869	0.903	0.823
		PEOU2	0.944		
	Self-satisfaction	SS1	0.802	0.853	0.660
		SS2	0.785		
		SS3	0.849		
	Technology self-efficacy	SE1	0.835	0.686	0.529
		SE2	0.600		
	Technology anxiety	ANX1	0.814	0.753	0.507
		ANX2	0.696		
		ANX3	0.612		
	Cognitive ability	CA1	0.712	0.764	0.522
		CA2	0.811		
		CA3	0.633		
Environmental factors (Cronbach's α=0.784)	Facilitating conditions	FC1	0.787	0.782	0.545
		FC2	0.669		
		FC3	0.754		
	Social influence	SI1	0.634	0.816	0.600
		SI2	0.885		
		SI3	0.784		

For the discriminant validity, this paper used the AVE of each variable and the square of the correlation coefficient of between the variables to test (Li *et al*., 2016). The results are shown in Table 4. All the numbers on diagonals were greater than those on non-diagonal lines, indicating that the measurement model has good discriminant validity.

Table 4 Discriminant validity test between variables

Variables	1	2	3	4	5	6	7	8	9
1 Usage Intention	0.572	—	—	—	—	—	—	—	—
2 Perceived usefulness	0.437	0.773	—	—	—	—	—	—	—
3 Perceived ease of use	0.128	0.164	0.823	—	—	—	—	—	—
4 Self-satisfaction	0.253	0.240	0.127	0.660	—	—	—	—	—
5 Technology self-efficacy	0.135	0.213	0.457	0.116	0.529	—	—	—	—
6 Technology anxiety	0.030	0.020	0.001	0.041	0.012	0.507	—	—	—
7 Cognitive ability	0.045	0.036	0.094	0.023	0.072	0.008	0.522	—	—
8 Facilitating conditions	0.114	0.140	0.276	0.132	0.308	0.002	0.040	0.545	—
9 Social influence	0.135	0.089	0.055	0.111	0.069	0.017	0.004	0.166	0.600

Note: The diagonal values represent the AVE value of each variable, and the non-diagonal values represent the square of the correlation coefficient between the variables.

4.2. Hypothesis test

Before the hypothesis test, the overall goodness of fit of the model was investigated. We used AMOS 21.0 to obtain the overall goodness of fit of the structural model of this paper and the relevant evaluation criteria (Table 5). As can be seen from Table 5, we know that all fitting indicators meet the standard, indicating that the structural model proposed in this paper can express the hypothetical relationship between variables.

Table 5 Structural model goodness of fit index results

Fitting index	Acceptable recommended value	Fitting value of the model
$\chi 2/df$	2.0-5.0	2.031
CFI	>0.90	0.962
GFI	>0.90	0.934
RMR	<0.05-0.08	0.049
RMSEA	<0.05-0.08	0.044
NFI	>0.90	0.929
IFI	>0.90	0.963
AGFI	>0.90	0.911

Note: The index of goodness of fit and evaluation criteria in this paper are compiled by referring to Hair *et al*., 1995.

We used the structural equation model to test the proposed hypotheses in this paper, and estimated the path coefficient between variables. In the end, we used Critical Ratio (C.R.) to test the estimated path coefficient value to judge whether or not the hypotheses were valid. Table 6 shows the results of path analysis assumed in the proposed structural model.

Table 6 Results of hypothesis test

Path description	Hypothesis	Path	Path coefficient	Result
The influence of personal factors on behavior	H1	Usage Intention ← Self-satisfaction	0.118***	support
	H2	Usage Intention ← Technology self-efficacy	-1.048	not support
	H3	Usage Intention ← Technology anxiety	0.047	not support
	H4	Usage Intention ← Perceived usefulness	0.505***	support
	H5	Usage Intention ← Perceived ease of use	0.065	not support
	H6	Usage Intention ← Cognitive ability	0.125*	support
The influence of environmental factors on personal factors	H7.1	Self-satisfaction ← Social influence	0.315***	support
	H7.2	Technology self-efficacy ← Social influence	-0.003	not support
	H7.3	Technology anxiety ← Social influence	0.186**	not support
	H7.4	Perceived usefulness ← Social influence	0.237***	support
	H7.5	Perceived ease of use ← Social influence	0.074	not support
	H7.6	Cognitive ability ← Social influence	0.002	not support
	H8.1	Self-satisfaction ← Facilitating conditions	0.585***	support
	H8.2	Technology self-efficacy ← Facilitating conditions	0.680***	support
	H8.3	Technology anxiety ← Facilitating conditions	-0.230**	support
	H8.4	Perceived usefulness ← Facilitating conditions	0.582***	support
	H8.5	Perceived ease of use ← Facilitating conditions	1.601***	support
	H8.6	Cognitive ability ← Facilitating conditions	0.450***	support
The influence of environmental factors on behavior	H7.7	Usage Intention ← Social influence	0.115**	support
	H8.7	Usage Intention ← Facilitating conditions	0.609	not support

Note: *p<0.05, **p<0.01, ***p<0.001.

The hypothesis test results show that in terms of personal factors that affect the elderly's intended uptake of gerontechnology, self-satisfaction (β=0.118, p<0.001), perceived usefulness (β=0.505, p<0.001), and cognitive ability (β=0.125, p<0.05) have significant positive impact – that is, H1, H4 and H6 are established. Technical self-efficacy, technical anxiety, and perceived ease of use do not have a significant impact on the elderly's intended use of gerontechnology. In terms of environmental factors, only the social influence (β=0.115, p<0.01) has a significant effect on the envisioned employment of gerontechnology; that is, H7.7 is established. At the same time, facilitating conditions have no significant direct impact on the elderly's plan to utilize gerontechnology, either.

In terms of the impact of environmental factors on personal factors, social influence has a significant positive impact on self-satisfaction (β=0.315, p<0.001) and perceived usefulness (β=0.237, p<0.001); specifically, H7.1 and H7.4 are established. Facilitating conditions affect self-satisfaction (β=0.585, p<0.001), technical self-efficacy (β=0.680, p<0.001), technical anxiety (β=-0.230, p<0.01), perceived usefulness (β=0.582, p<0.001), perceived ease of use (β=1.601, p<0.001) and cognitive ability (β=0.450, p<0.001). They have significant effects; namely that H8.1, H8.2, H8.3, H8.4, H8.5 and H8.6 are all established. In summary, the final result of the structural model is shown in Fig. 4.

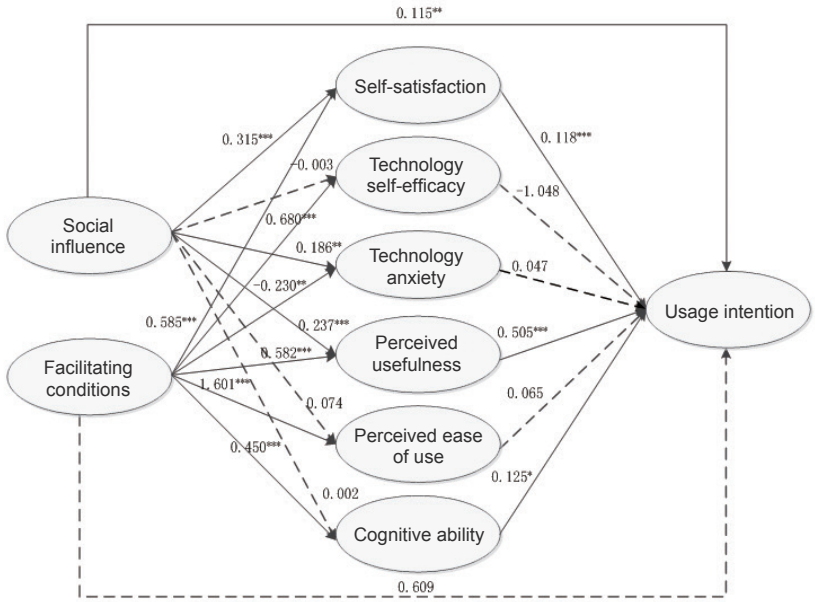

Fig. 4 Structural equation model analysis results

Note: *p<0.05, **p<0.01, ***p<0.001 (the dotted line indicates that the effect is not significant).

4.3. Results analysis

In order to evaluate the extent to which each variable in this paper affects the elderly's intention of using gerontechnology, the direct, indirect, and total effects of each variable after standardization were analyzed (As is shown in Table 7).

Table 7 Direct effect, indirect effect and total effect of each variable on usage intention

	Variables	Direct effect	Indirect effect	Total effect
Personal factors	Self-satisfaction	0.118	—	0.118
	Technology self-efficacy	NS	—	NS
	Technology anxiety	NS	—	NS
	Perceived usefulness	0.505	—	0.505
	Perceived ease of use	NS	—	NS
	Cognitive ability	0.125	—	0.125
Environmental factors	Social influence	0.115	0.157	0.272
	Facilitating conditions	NS	0.419	0.419

Note: NS means that the impact is not significant.

The results show that in terms of personal factors, perceived usefulness was the strongest predictor of an intention to use gerontechnology, followed by cognitive ability and self-satisfaction. In terms of environmental factors, facilitating conditions have the greatest influence, but they all indirectly affect the usage intention through personal factors. Social influences have both direct and indirect effects on the planned uptake. In general, the indirect effect was greater than the direct effect. It proves that the behavior

of seniors in accepting gerontechnology as proposed in this paper was in line with the rationality of Social Cognitive Theory. The results can be discussed as follows.

In terms of personal factors, perceived usefulness has a significant positive impact on the elderly's usage intention of gerontechnology, while the perceived ease of use has no significant impact, which is consistent with the results of Pan *et al*.'s (2010) research on the influence of seniors' targeted use of the Internet. At the same time, Mo *et al*. (2015) also learned that when the middle and old age users of Wuhan receive mobile health services, what they value more highly is whether the service is useful for them. In addition, by analyzing the demographic information of this survey, it was found that more than half (50.19%) of the interviewees were people aged 55 to 64, and nearly half (40.89%) of the interviewees have a college education level or above. This type of "future elder people", who are relatively younger and better educated, are more tolerant of the ease of operation of gerontechnology (Li *et al*., 2017). It seems that the "useful" gerontechnology is more important than the "easy to use" gerontechnology, which brings new enlightenment for enterprises' future research and development of gerontechnology. Technology anxiety does not negatively affect the elderly's usage intention of gerontechnology as expected, which is consistent with the results of Mo and Deng (2015). In China, most seniors live with their families. Thanks to the support and help in this environment, they will not be overly worried about problems when operating gerontechnology, and they can deal with and successfully respond to the conditions that may occur during its use. Therefore, technology anxiety is not an important reason hindering their acceptance of gerontechnology. The reason why technology self-efficacy does not have a significant impact on the seniors' expected use of gerontechnology could be that seniors can basically operate gerontechnology proficiently for higher popularity. As for high-tech products (such as remote care and medical technology), because they are relatively rare on the market, the concept of these products cannot be materialized by seniors. Therefore, they cannot judge effectively whether they have sufficient capabilities to use this kind of specific gerontechnology. Cognitive ability has a significant positive effect on the usage intention of gerontechnology by elderly people in Beijing. This result is consistent with the results of Chen (2014) in Hong Kong and Czaja (2006) in Europe. Good cognitive ability not only determines the seniors' understanding of gerontechnology, but also determines their smooth operation of products. Self-satisfaction positively affects the elderly's determined use of gerontechnology, which further strengthens Deng's point of view (2014). He found that self-fulfillment needs have a significant positive impact on seniors' intention to use mobile health services. The last requirement of self-actualization needs is the sense of accomplishment of seniors (Maslow, 1970). The self-satisfaction generated by the successful use of gerontechnology is a manifestation of the sense of self-fulfillment, which can stimulate seniors' acceptance of gerontechnology.

In terms of environmental factors, social influences have a significant positive impact on the elderly's usage intention of gerontechnology, which is consistent with the results of Macedo (2017) on the acceptance of information and communication technology by seniors in Portugal. The direct effect of facilitating conditions on the planned application is not significant. Although it is contrary to the conclusion of Macedo (2017), it is consistent with the research results of Hoque (2017) on seniors in Bangladesh receiving mobile health services. This shows that the reasons for the instability of the facilitating conditions on seniors' acceptance of gerontechnology might be due to regional differences. Further research is needed to conduct more extensive and in-depth discussions on this issue. In fact, this situation is not surprising in China. Because of the "filial piety" culture, the facilitating conditions of seniors in acquiring and learning gerontechnology often come from their children. Therefore, seniors

have no obvious perception that facilitating conditions directly affect their use of gerontechnology. Through further exploration of the "black box" between environmental factors and usage intention, it is found that, although facilitating conditions have no direct or significant impact on intended use, it has an indirect effect by influencing the seniors' perceived usefulness, self-satisfaction and cognitive ability. It is inferred from this that when seniors are equipped with the resources and knowledge needed to use gerontechnology, their planned use of it will be enhanced through the promotion of personal factors. In addition, social influence also affects the proposed use of gerontechnology by influencing the self-satisfaction and perceived usefulness of seniors. This shows that seniors do not ignore the attitudes and opinions of family, friends and peers towards products, and that their opinions will increase the possibility of seniors' accepting gerontechnology. On the whole, when it comes to the elderly's usage intention of gerontechnology, the overall influence of facilitating conditions is greater than the social influence. With the decline of the physical functions of seniors, their desire to track and pursue new things is generally less than that of young people. What they are interested in is often those gerontechnologies that they think are helpful and have available resources and technical support. These gerontechnologies can not only reduce seniors' technical anxiety, but also increase their self-satisfaction and technical self-efficacy. Therefore, providing real support and help for seniors is the best way to encourage them to accept gerontechnology innovation.

5. Discussion and Conclusions

In the context of the rapid development of intelligent technology and population aging, how to understand the influencing factors and behavioral characteristics of the seniors' acceptance and usage of gerontechnology is of vital importance to enterprises' R&D strategic decisions and government policy formulation. This paper proposed a systematic gerontechnology acceptance model for seniors from both environmental and personal factors, one which explores the influencing aspects and behavioral characteristics of the seniors' acceptance and usage of gerontechnology. We selected the Beijing senior citizens as a case study and found the proposed model to be valid and flexible. The results confirm the rationality and effectiveness of applying social cognition theory in studying the behavior of seniors' acceptance of gerontechnology.

The research results will provide decision support for enterprises to develop gerontechnology for the elderly living in Beijing. For example, self-satisfaction and perceived usefulness are positive influencing factors, and their influence on older people's proposed use of gerontechnology mainly depends on the feelings and experiences that the gerontechnology themselves bring to seniors. Therefore, in the development of gerontechnology for seniors, enterprises should pay more attention to these two factors. Social influence and facilitating conditions are important influencing factors, and their influence on older people's proposed use of gerontechnology mainly comes from the external environmental support. Therefore, government should improve the infrastructure construction for seniors, and provide gerontechnology products suitable for seniors in communities, elderly activity centers and other places, and create convenient conditions for more seniors to access gerontechnology. For enterprises, when marketing gerontechnology products for seniors, they should not only target seniors, but also target groups that serve the seniors, such as their family members and the staff of elderly activity centers. Through their knowledge popularization and operation demonstrations of gerontechnology products to the seniors, the perceived usefulness of the seniors may increase, which in turn increases the possibility of

the seniors using gerontechnology products.

This study has some limitations and issues to be considered. Although the participants are selected randomly, the bias and limitations of the selection are inevitable. For example, when we selected the elderly in Beijing for questionnaire interviews, we did not involve older people in the suburbs of Beijing, or older people who are engaged in manual labor occupations. We also did not choose the foreign elderly in Beijing as our research object. Therefore, the applicability and universality of our research results need to be further tested and verified. This requires us to conduct larger-scale sample selection and analysis in the future.

Acknowledgments

This paper is supported by the National Social Science Foundation of China (Grant 17ZDA119).

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