A Study on Technology Acceptance Model of Smart Homes for Future Elderly: From the Perspective of Perceived Value and Perceived Risk

劉, 玉琪

https://hdl.handle.net/2324/4496068

出版情報：Kyushu University, 2021, 博士（芸術工学），課程博士
バージョン：
権利関係：

A Study on Technology Acceptance Model of Smart Homes for Future Elderly：From the Perspective of Perceived Value and Perceived Risk

Yuqi Liu

A Study on Technology Acceptance Model of Smart Homes for Future Elderly：From the Perspective of Perceived Value and Perceived Risk

将来の高齢者のためのスマートホームの技術受容モデルに関する研究
——知覚価値と知覚リスクの観点から

Yuqi Liu
劉玉琪
Sept 2021

Abstract

Smart home, as one of the most prosperous industries of the Internet of Things, has tremendous potential in helping the elderly aging in place and dealing with the challenges of aging society. However, compared with the optimistic estimates of related industry and academia, currently, the acceptance and market penetration of smart homes for the elderly stays extremely low. The essential problem is that the existing smart home products and services for older adults could not meet their core value demand, and the application of technology and service delivery have not been able to eliminate or reduce their worries and perceived risks. As the most populous country in the world, China is one of the countries with the fastest aging process in the world. In the upcoming future, China will become the country with the most aging population globally which will bring a huge burden to the Chinese government and society. A huge base of aging population also indicates that there is an enormous blue ocean of business opportunities in the Chinese aging industry.

Targeted on the future elderly aged from 45-60 in China, this research develops the perceived value and perceived risk scales of smart homes for future elders by following the standard scale development process. The perceived value scale is consisted of perceived benefit and perceived cost scale, among which the perceived benefit scale contains eight factors with the integration of the PERMA-V wellbeing model, they are independence, healthcare, safety, positive emotion, engagement, relationship, meaning, and achievement, in total 38 measurement items; the perceived cost scale consists of three factors, namely monetary cost, study cost, and space cost, in total 15 items. And the perceived risk scale is made up of ten factors, namely privacy & security risk, physical risk, technological risk, performance risk, service risk, financial risk, psychological risk, industry & market risk, social support risk, policy & law risk, in total 70 items. The combination of these two scales could comprehensively evaluate the elderly's perception of smart homes from the value creation and risk avoidance perspective. Moreover, based on the development of perceived value and perceived risk scales, this study further develops a smart home technology acceptance model for the elderly by using perceived value and perceived risk as the core variables through structural equation modeling. The result shows that the perceived benefit has a significantly positive effect on the attitude of future elders toward smart home using, which will further affect their behavioral intention to use. In contrast, the perceived cost and perceived risk exert a mainly negative effect in the model. Thus, maximizing the perceived benefit in the eight dimensions mentioned above, as well as controlling, reducing, or eliminating perceived risk and perceived cost is the core principle to improve the acceptance and adoption of smart homes for future elders.

The research breaks through the limitation of the conventional technology acceptance model and makes the value evaluation of a high-tech applications for the elderly group much more precise and profound. The results of this research can provide guidelines and help corresponding designers, developers, industry practitioners, and policymakers to accurately grasp the value needs of the elderly and clarify the potential risks that should be avoided during the products and service developing and delivery process. So that the maturity and market penetration of the smart home industry for older adults could be improved, the social pension burden could be relieved, and the all-around wellbeing of the elderly could be promoted, which endow the research with crucial theory and practice value.

Keywords: internet of things; smart homes; older adults; perceived value; perceived risk; technology acceptance model; scale development; structural equation modeling.

Contents

Chapter 1
Introduction

Chapter 1 Introduction

This chapter gives a brief introduction about the dissertation, mainly including the following contents: research background, purpose and significance, innovation point, content and structure, research method.

1.1 Research background

The aging population has become one of the most significant social transformations in the 21st century [1]. With the improvement of living standards and the development of science and medical technology, humans live a longer life nowadays. Due to the low birth rate and longer life expectancy, a crowd of countries is currently facing the challenges of aging society [2]. As the most populous country in the world, China is one of the countries with the fastest aging process all of the world [3]. In 2025, China's population over 60 years old will reach 300 million, which will make China become an over-aged country. By 2035, China will have 400 million elderly people, and by 2050, this data will reach 487 million, accounting for 34.9% of the total population [4]. It can be seen that, in the upcoming future, China will become the country with the most aging population in the world. This kind of population structure could bring a huge burden to the Chinese government and society, which also indicates that there is an enormous blue ocean of business opportunities of the Chinese aging industry [5].

According to an existing survey, 90% of old Chinese people choose to live at home after retirement [6]. However, with the decline of physical and social functions, the independence and safety of their lives could not be guaranteed in the conventional home environment [7]. Smart homes use comprehensive wiring technology, information communication technology, security technology, automatic control technology, audio, and video technology, etc. to build efficient residential facilities and home management systems of schedule affairs to improve the convenience, comfort, safety, environmental friendliness, and artistry of the home life, which make it has huge potential in helping the elderly aging in place [8,9]. It can not only make up for the shortage of service labor in the elderly care industry, relieves the pressure and burden of social pension, but also can provide precise, efficient, high-quality, and convenient services to meet the elderly’s diverse demand and help them live an independent, safe and happy life in their familiar environment [10-13]. In addition, through the collection of elderly-related data, the establishment of a basic information database for elderly behaviors could be realized. It will provide a basis for the government to publish related policies and improve their service ability for the elderly so that the burden of social pension could be reduced, the social welfare, as well as the World Health Organization (WHO) goals of healthy aging and active aging, could be promoted [14]. With the promotion of the Chinese government's smart pension policy, smart homes will have broad market prospects in China in the future. However, compared with the optimistic estimates and high expectations of relevant industry and academia, currently, the acceptance and market penetration of smart homes for older adults stays extremely low [15,16]. The essential problem is that the existing smart home products and services for the elderly could not meet their core value needs, and the application of technology and service delivery have not been able to eliminate or reduce their worries and perceived risks toward the usage of smart homes.

Currently, the majority of the research and development of smart homes targets on the young group while the older adults receive little attention. At the same time, numerous researches aiming at elderly groups concentrate on the healthcare and physiological aspects of the elderly while the impact of the home environment on the mental state and all-around happiness of the elderly has been rarely discussed. This is a very big misunderstanding. It is true that the major problem for the elderly is the physical and safety issues, but with the improvement of living standards and medical science, there are more and more healthy elderly people [17], and their needs for spiritual life are growing and stay strong [18]. At the same time, the mental life of the elderly often determines their mental state, and the mental state has a significant impact on their physical health [19]. Loneliness and depression are often the real culprits behind the worsening physical health of the elderly. Therefore, the design and development of smart homes for the elderly should not only focus on the conventional physical aspect but also emphasize the satisfaction of their psychological needs [20-22]. Generally speaking, the current studies of smart homes for the elderly are more limited to the development and consideration from a single technology perspective, lacking insight into their core value demands and not well-circumvented users' anxiety and perceived risks from a humanism aspect [23], industry and technology development are immature[15], market penetration and the users' acceptance stays low[16].

1.2 Research purpose and significance

1.2.1 Research purpose

In view of the lack of core value insights and anxieties identification of smart home products and services for the elderly, this research aims to develop the perceived value and perceived risk scales of smart homes for older adults and construct a technology acceptance model based on these two core variables.

The author followed the standard scale development process to conduct exploratory factor analysis (EFA) and confirmatory factor analysis (CFA) in SPSS 25.0 and AMOS 25.0 to gain the perceived value scale and perceived risk scale through the investigation of the future elderly group aged from 45-60 in China. Moreover, based on these two scales, a technology acceptance model of smart homes for future elders has been proposed and verified through structural equation modeling (SEM) in AMOS 25.0. The results of the research could provide guidance and references for the development and maturity of smart homes for future elders from a user-centered perspective, improve their quality of life (QOL), and promote their all-around happiness through the application of smart technology.

The reasons why the research targets on 45-60 years old group are as follows: First, people over 60 years old are defined as senior citizens in China, those aged from 45-60 will transform into aging population gradually in the coming 15 years, who are the main groups of future elders. Second, these group people have witnessed and experienced the born and rapid development of China's Internet and been deeply influenced by information technology. They are more likely to be the early adopters and users of smart homes when they are getting old compared to the aging group now. Third, the development of smart home technology, the maturity of related industries and markets, the users' perception and adoption of smart homes are still in their initial stage. They all need time to be optimized, promoted, and diffused. Since information technology nowadays is experiencing unprecedented development and advancement, in 15 years, there will be more possibilities for smart homes from the technology, service, industry, market, social, and policy level. The maturity of these conditions could promote the elderly all-around happiness from a comprehensive perspective including the physical, psychological and cognitive aspects through smart home technology, which is the core proposition of this research.

1.2.2 Research significance

1. Theoretical significance

This research has developed a smart home perceived value scale and perceived risk scale for the elderly and proposed a smart home technology acceptance model based on these two core variables. First, it has complemented the gap of current value evaluation and risk identification of emerging technology for the elderly group. The core value needs and typical characteristics of the aging group have been well considered during the scale development process, which makes the perceived value and perceived risk scales is specifically suitable for older adults. Second, the research has broken through the limitation of the conventional technology acceptance model, which takes the perceived usefulness and perceived ease of use as the core variables. Nowadays, due to the development of information communication technology (ICT), customers could form recognition and perceptions about certain products and services via multi-channels and a variety of ways, like offline experience, online information, and comments, mass media, broadcasting, pictures, radios, videos, etc., and then decide whether to purchase and use certain products and services. Moreover, users' requirements are diverse and complex, which are far more beyond the functional demand. Also, for the integrated system platform like smart home, it involves complicated problems like privacy, security, and ethical issues, which are out of the range of usefulness and ease of use. Thus, the traditional technology acceptance model could not respond to the diverse needs and technology harmfulness of complex and intelligent systems platforms, so that reshape the technology acceptance model through the two essential variables, perceived value and perceived risk, could provide a profound and comprehensive insight into the acceptance motivation of users, which is of great theoretical significance.

2. Practical significance

The results of this research can provide guidelines and help corresponding designers, developers, industry practitioners, and policymakers to accurately grasp the value needs of the elderly and clarify the potential risks that should be avoided during the products and service development and delivery process. It can help the elders aging in place and is beneficial to maximize the perceived value of smart homes for the elderly. It can improve the smart home acceptance and adoption rate to speed up the maturity of the smart home industry for the aging groups. It can help advance technologies such as the internet, big data, and cloud computing, artificial intelligence, etc., to combine together in dealing with the issues and challenges of the aging society so that the social pension burden of government and society could be relieved, the QOL and all-around wellbeing of the elderly could be promoted, which endow the research with crucial practice value.

1.3 Research innovation point

The innovation points of this research are mainly reflected in the following four aspects:

1. Development of the smart home perceived value scale for the elderly: The development of the perceived value scale is based on the PERMA-V wellbeing model. It reveals the value needs

of the elderly deeply and comprehensively and how smart homes could bring wellbeing to older adults from the physical, psychological, and cognitive perspectives. Happiness is an eternal goal pursued by human beings no matter how time changes and how technology advances. The existing perceived value scales are not targeted on the elderly customer group, no need to mention aiming at the smart technology toward the aging group. They are general to evaluate a product or service in terms of function, emotion, and social aspects, while the evaluation items are not specific and suitable for older adults. There is no certain perceived value scale for smart homes toward older adults up until now. Thus, the scale development of this research aiming at the evaluation of the perceived value of intelligent technology application for older groups is a valuable exploration that has breakthrough significance.

2. Development of the smart home perceived risk scale for the elderly: The development of the perceived risk scale comprehensively analyzes and presents the risk factors affecting the perception and acceptance of the elderly toward smart home from the macro to the micro perspective. It covers national policy and law, industry and market standards, social support, services responsiveness, technology uncertainty, privacy, and security, etc., as well as the psychological risk and performance risk of the elderly group. The maturity and development of emerging technology are inseparable from the support and maturity of the macro and micro level conditions. Our research presents a comprehensive perceived risk measurement scale for the application of relevant smart technologies in dealing with aging challenges and issues. It is fundamentally different from other studies that only discuss a few aspects of risk or ignore the specific characteristics of older adults.

3. Construction of the technology acceptance model of a smart home for the elderly based on perceived value and perceived risk: the smart home is an integrated system of smart technology which is different from conventional single intelligent technology product or service so that its acceptance and adoption should be considered in a systematic level. The ultimate reason for users to accept the relevant products and services of smart homes depends on to what kind of extent these technologies can satisfy their value demands. This research breaks through the limitation of the conventional technology acceptance model, which could not respond to the diverse value needs of customers and ignore the technology uncertainty and negative effects, replaces the variables perceived usefulness and perceived ease of use with perceived value and perceived risk. The research integrates the technical value and risk of smart homes for the elderly into the construction of the technology acceptance model from a systematic and comprehensive perspective.

4. Provision of a method for the value evaluation of emerging technology application for the aging group: Although this research mainly focuses on the development of value measurement scales and acceptance model of the smart home industry, it is also applicable to other corresponding emerging smart technologies which targeted on older adults. The results of this research can help corresponding designers, developers, and industry practitioners to quickly and accurately grasp the value needs of the elderly and clarify the potential risks that should be avoided during the products and service development and delivery process, which is of significant value.

5. Integrate the PERMA-V model into the technology application field. The PERMA model is a model of human psychological wellbeing. Martin Seligman, the "father of positive psychology" in the book "Flourish: A visionary new understanding of happiness and wellbeing" proposed

it. It includes five aspects: P (positive emotion), E (engagement), R (relationship), M (meaning) and A (accomplishment). Martin Seligman points out that the overall happiness of man must be vigorous development, full experience, and display in these five dimensions. In order to present the comprehensive description of wellbeing through this model, the dimensions have been updated to six in 2011, which adding the V(Vitality) to represent the physical foundation of happiness. The PERMA-V model is originated from the psychological field to indicate the structure of wellbeing of the individual. In this study, the author integrates this meaningful theory with the application of smart home technology to construct all-around happiness for older adults, which remains an innovative cross-field integration and provides a new approach for the exploration of how smart technology could sculpt wellbeing for humankind.

1.4 Research content and structure

The research is mainly divided into seven chapters. Chapter 1 is the comprehensive description of the research, including the research background, research purpose, innovation point, research content and structure, research method. Chapter 2 is a summary of the current situation of smart home development and a literature review of relevant existing research and theories. Chapter 3 is the analysis of the physiological, psychological, cognitive and consumption characteristics of elderly people. Chapter 4 is the content of study 1, the scale development of the perceived value of smart homes for older adults; Chapter 5 is the content of study 2, the scale development of perceived risk of smart homes for the elderly. Chapter 6 is the content of study 3, which is the technology acceptance model of smart homes for elderly people based on the perceived value and perceived risk; After getting a comprehensive technology acceptance model, in Chapter 7, the author gives the conclusion and summary of the whole dissertation and put forward the development strategies of smart homes industry for the elderly based on the previous research. The limitation of the whole dissertation and the future research direction has also been clarified in this chapter. For more details about the content of each chapter, please refer to the frame diagram below:

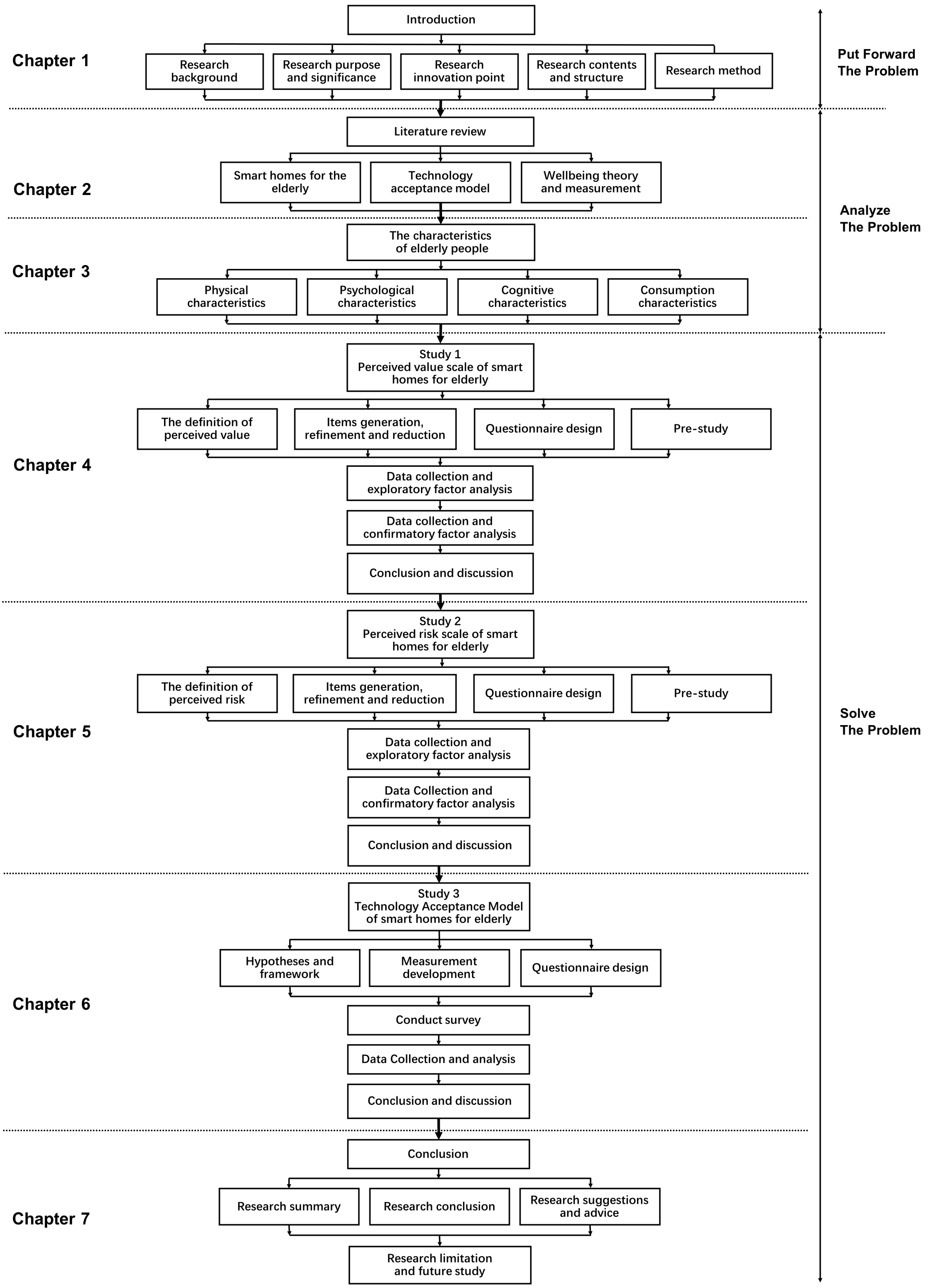

Figure 1.1 Research structure

1.5 Research methods

The research mainly adopted the following six research methods:

1. Literature review method

Through the research, induction, and analysis of a large number of documents on the internationally renowned databases Web of Science, Scopus, and IEEE Explorer, the value factors and risk factors, as well as their measurement items of the smart home for the elderly, are initially summarized which give a foundation for the further development of the perceived value and perceived risk scale. At the same time, the sorting and analysis of previous studies provide significant inspiration for other study methods and the procedure of this research.

2. Interview research method

During the scale development of perceived value and perceived risk, as called study 1 and study 2, the author conducted interviews with future elders aged 45-60 and experts whose research field is aging society to check the rationality of the preliminary value and risk factors extracting from existing literature, optimize the statement and numbers of measurement items and add important items which have not been considered before. This step is called the refinement and item reduction of scale development.

3. Questionnaire survey method

The questionnaire survey method has played an important role in the three main studies of this dissertation. For study 1 and study 2, the author conducted a pilot study before the large-scale questionnaire survey to optimize the question expressions and make the language easier to understand. Then, two main large-scale questionnaire surveys were carried out using the revised questionnaire to collect data for the exploratory factor analysis and confirmatory factor analysis of relevant scale development. For Study 3, the author combined the generated scale of perceived value and perceived risk in study 1 and study 2 to conduct a large-scale questionnaire survey to collect data for further model fit and hypotheses test of the technology acceptance model.

4. Statistical analysis method

The research used SPSS 25.0 for statistical analysis of the collected data in Study 1, Study 2, and Study 3, involving descriptive statistical analysis for demographic information, factor analysis, reliability and validity analysis, Cronbach α coefficient method, etc.

5. Scale development method

The research followed the standard scale development process in study 1 and study 2, which including item generation, refinement, and reduction, questionnaire design, pre-study, exploratory factor analysis, confirmatory factor analysis. During these steps, the exploratory factor analysis of study 1 and study 2 was conducted through SPSS 25.0, and the confirmatory factor analysis was conducted in AMOS 25.0.

6. Structural equation model method

The research process of study 3 is to put forward hypotheses based on theoretical analysis and then conducting a questionnaire survey to collect data for empirical testing, which mainly used the structural equation model (SEM) method. For study 3, it initially conducted the descriptive analysis, reliability, and validity test. Then, AMOS 25.0 software was used for the evaluation of overall model adaptation and model fit criteria. Last, SEM was performed to check path analysis for hypotheses evaluation.

Reference

1. Harper, S. Ageing 2000—questions for the 21st century. Ageing and Society 2000, 20, 111–122.
2. World Population Ageing 2019 Highlights. 2019.
3. Statista. Aging population in China. 2020.
4. China Development Report 2020: The development trend and policy of China's aging population. Development Research Center of the State Council. 2020.
5. Banister, J.; Bloom, D. E.; Rosenberg, L. Population Aging and Economic Growth in China. The Chinese Economy 2012, 114–149.
6. Jingcheng G. International Comparison and Reference on Home Pension Service Mode. Social Security Studies 2010,1.
7. Demiris, G.; Hensel, B. K.; Skubic, M.; Rantz, M. Senior residents' perceived need of and preferences for "smart home" sensor technologies. International Journal of Technology Assessment in Health Care 2008, 24, 120–124.
8. Alam, M.R.; Reaz, M.B.I.; Ali, M.A.M. A review of smart homes—Past, present, and future. IEEE transactions on systems, man, and cybernetics, part C (applications and reviews) 2012, 42, 1190-1203.
9. Chan, M.; Campo, E.; Estève, D.; Fourniols, J.-Y. Smart homes — Current features and future perspectives. Maturitas 2009, 64, 90–97.
10. Morris, M.E.; Adair, B.; Miller, K.; Ozanne, E.; Hansen, R.; Pearce, A.J.; Santamaria, N.; Viega, L.; Long, M. and Said, C.M. Smart-home technologies to assist older people to live well at home. Journal of aging science 2013, 1, 1-9.
11. Cai F.; WANG M.Y. Labor Shortage in an Aging but not Affluent Society. China Opening Herald 2006,1,31-39.
12. Gomez, C.; Paradells, J. Wireless home automation networks: A survey of architectures and technologies. IEEE Communications Magazine 2010, 48, 92–101.
13. Darianian, M.; Michael, M. P. Smart Home Mobile RFID-Based Internet-of-Things Systems and Services. 2008 International Conference on Advanced Computer Theory and Engineering 2008.
14. Tang, X.; Hong, M. Research on the Exploration of PPP Model in Smart Home Pension Projects. Engineering Economy 2018, 7, 15.
15. Balta-Ozkan, N.; Davidson, R.; Bicket, M.; Whitmarsh, L. Social barriers to the adoption of smart homes. Energy Policy 2013, 63, 363–374.
16. Pal, D.; Papasratorn, B.; Chutimaskul, W.; Funilkul, S. Embracing the Smart-Home Revolution in Asia by the Elderly: An End-User Negative Perception Modeling. IEEE Access 2019, 7, 38535–38549.
17. Beard, J.; Officer, A.; de Carvalho, I.; Sadana, R.; Pot, A.; Michel, J.; Lloyd-Sherlock, P.; Epping-Jordan, J.; Peeters, G.; Mahanani, W.; Thiyagarajan, J.; Chatterji, S. The World report on ageing and health: a policy framework for healthy ageing (accessed May 06, 2020).
18. Howell, S. C. The potential environment: Home, technology, and future aging. Experimental Aging Research 1994, 20, 285–290.

19. McKee, K.; Wilson, F.; Chung, M.; Hinchliff, S.; Goudie, F.; Elford, H.; Mitchell, C. Reminiscence, regrets and activity in older people in residential care: Associations with psychological health. British Journal of Clinical Psychology 2005, 44, 543-561.
20. Chan, M.; Estève, D.; Escriba, C.; Campo, E. A review of smart homes—Present state and future challenges. Computer Methods and Programs in Biomedicine 2008, 91, 55–81.
21. Percival, J.; Hanson, J. Big brother or brave new world? Telecare and its implications for older people's independence and social inclusion. Critical Social Policy 2006, 26, 888–909.
22. Demiris, G.; Rantz, M. J.; Aud, M. A.; Marek, K. D.; Tyrer, H. W.; Skubic, M.; Hussam, A. A. Older adults' attitudes towards and perceptions of 'smart home' technologies: a pilot study. Medical Informatics and the Internet in Medicine 2004, 29, 87–94.
23. Marikyan, D.; Papagiannidis, S.; Alamanos, E. A systematic review of the smart home literature: A user perspective. Technological Forecasting and Social Change 2019, 138, 139-154.

Chapter 2
Literature Review

Chapter 2 Literature Review

2.1 Research purpose

The main purpose of this chapter is to build a theoretical foundation for the whole thesis. First, it discusses the concept, history, the development status of smart homes, as well as the previous research about the application of smart homes in the aging field. Second, the relevant researches of the technology acceptance model are analyzed. Third, wellbeing theory and corresponding measurement scale are presented. Last but not least, the direction and theories basis of this research are clarified.

2.2 Research method

This chapter mainly adopts two research methods. The first one is literature review to summarize and present the smart home concept, history, development status, and research situation, as well as the technology acceptance model and wellbeing theories. The second one is inductive analysis to find the gap in existing studies and reflect the direction and method of this research. To be specific, the literature review provides the evidence and foundation to the inductive analysis and makes the reasoning process and conclusions more convincing and credible.

2.3 Smart homes for the elderly

2.3.1 The definition and concept of Smart homes

Smart homes are human residential platforms using integrated wiring technology, network communication technology, security technology, automatic control technology, audio and video technology to integrate facilities related to home life to build efficient residential facilities and home environment with a management system for schedule affairs. Based on the Internet of Things technology, a family ecosystem composed of hardware, software, and cloud computing platforms can realize functions such as remote control, the interconnection between different devices, and self-learning of intelligent systems, etc. Through the collection and analysis of user behavior data to provide users with personalized services, improve home safety, convenience, comfort, and artistry, make home life safer, and even realize an environmentally friendly and energy-saving living space. It is the embodiment of the Internet of Things which can connect various devices and provide home appliance control, lighting control, indoor and outdoor remote control, anti-theft alarm, environmental monitoring, HVAC control, infrared forwarding, and programmable timing control, etc. Compared with an ordinary home, smart home not only has traditional living functions, can provide a comfortable, safe, high-grade, and pleasant living space, but also transforms the interaction between users and systems from the original passive mechanism to active, intelligent response, provides a full range of information exchange to enable the family to maintain smooth information exchanges with the external world which greatly improve their quality of life [1-4].

2.3.2. The development stages of smart homes

In the 1930s, some people put forward the idea of home automation at the World Expo.

Until 1984, United Technology Corporation applied equipment information and integrated concepts to buildings, and the first intelligent building appeared in Connecticut. After that, a system that integrated the independent functions of electrical appliances, communication equipment, and security devices was called "smart home" in the United States, and smart homes have been introduced to the business world since that time. According to the general understanding of the industry, smart homes will roughly go through four stages of development:

The first stage, the home automation stage. It is the basis for the automatic control of smart homes. Strictly speaking, this stage cannot be regarded as a smart home but only a prototype of a smart home. One of its most notable forms is the automatic management of electrical products, such as home appliances, curtains, and garage doors, etc.

The second stage, the single product stage. It is also the primary stage of smart home, mainly includes single products, such as smart switches, smart sockets, smart door locks, smart cameras, smart bulbs, smart speakers, smart TVs, etc. The most obvious feature of this stage is that there are many single smart home products on the market, and they exist in isolation from each other and cannot be connected or communicated with each other. In this stage, traditional companies are gradually developing towards intelligence, and emerging technology companies are committed to the research and development of novel smart items.

The third stage, the Internet of Things stage. It is a real smart home. This stage is mainly focusing on developing the breadth of smart homes, and the keywords are systemization and sceneization. Among them, systemization is the thinking of interconnection of all things to solve the problem of fragmentation of smart homes, and integrate them into a system, which is convenient for management and control; sceneization is to shape the intelligent life scenarios by permutation and combination on the basis of different systems. This stage can realize data interoperability between products of different categories. The linkage between multiple products allows users to customize different scenarios at will and also meets the various demands of users. The control at this stage is mainly controlled by artificially launching commands. For example, the smart bracelet can obtain the weight, BMI (Body mass index), body fat percentage, and other health data detected by the body fat scale, and monitor the user's sleep quality, exercise, and diet records based on these health data to cultivate a healthier lifestyle for the users. In this stage, home sceneization has also become an enterprise focus of smart home companies.

The fourth stage, the artificial intelligence stage. It is to combine smart homes with artificial intelligence technology. This stage is mainly focusing on the in-depth mining of the "intelligence" aspect of smart homes. Big data and cloud computing capabilities will be fully utilized. Deep learning, computer vision, and other technologies will also be used to realize the learning, thinking, simulation, and consciousness of smart homes. The systematic realization of intelligence is the result of cross-product data exchange and interaction. Different products can not only exchange data but also transform it into active feedback without the command and intervention from users. For example, if the smart bed senses that the user is hot and sweats, it will actively transmit the data to the smart air conditioner, and the air conditioner is activated to provide a more comfortable temperature for the living space. Or when the smart box detects that the environmental humidity is too heavy, it will transmit the information to the dehumidifier, and the dehumidifier will adjust the space humidity in real-time. This kind of systematic intelligence is based on the premise of having perfect intelligent single products and service systems, which can realize cross-product and cross-system interaction. It requires all products and systems in the smart home to operate on a unified platform and follow a unified standard. This also means that manufacturers that have already entered the field of smart homes need to consider whether their set of smart product gateway devices can be grafted onto the big platform in the future. Smart homes will go through a long development process, and various smart home companies are currently working towards the fourth stage.

2.3.3. The development status of smart homes in China

Since the world's first smart building appeared in the United States in 1984, the concept of smart home has been introduced to China for more than 30 years. From 2003, China successively introduced some smart home systems to the market. Led by the development of artificial intelligence and Internet of Things technology, the smart home industry is booming. From 2014 to 2019, China's smart home market developed rapidly, with the market size growing from 72 billion yuan to 211.8 billion yuan. Data shows that smart products have become a hot spot in China's consumer market. From sweeping robots to smart speakers, smart child companion robots to smart door locks, etc. More and more smart products have become synonymous with a sense of the future. Looking at the development process of smart homes in China, it can be roughly divided into the following five stages.

- **The first stage: the budding period (1994-1999).** This is the first stage of smart home development in China. The entire industry is still in a stage of concepts adoption and product recognition. At this time, no professional smart home manufacturers have appeared. Only LivingLab was the first to enter this market. Today, the products are continuously improved and upgraded, and at the same time, a considerable domestic market was forming.
- **The second stage: the pioneering period (2000-2005).** At this stage, more than 50 smart home R&D(Research and development) and production enterprises have been established in China, mainly located in Shenzhen, Shanghai, Tianjin, Beijing, Hangzhou, Xiamen, and other big cities. The marketing and technical training systems of smart homes have been gradually improved. At this stage, overseas smart home products have basically not entered the domestic Chinese market.
- **The third stage: the hovering period (2006-2010).** After 2005, the brutal growth and vicious competition of smart home companies in the previous stage has brought great negative effects to the smart home industry, which including excessively exaggerating the functions of smart homes but actually unable to achieve the related effect, manufacturers only care about the development of agents but neglected the training and support, which has caused operation difficulties, and the unstable products have led to a high complaint rate from users. From 2005 to 2007, dozens of smart home manufacturers withdrew from this market, and many local agents closed their businesses. The majority of smart home companies that have persisted have also experienced the pain of downsizing in recent years. In this period, foreign smart home brands have secretly entered the Chinese market, some domestic companies that still survived have also made their way to find their development directions.
- **The Fourth stage: the development period (2011-2020).** Since 2011, the market has clearly witnessed a momentum of growth. The high volume growth of smart home products shows that the industry has entered an inflection point, a new round of integration and evolution from the hovering period. On the one hand, smart homes have entered a relatively rapid development stage; on the other hand, agreements and technical

standards have begun to interoperate and merge actively, and industry mergers and acquisitions have begun to emerge which even become the mainstream in this industry.

- **The fifth stage: the rapid integration period (2021-2025).** With the emergence of various high technologies such as artificial intelligence, big data, 5G, and cloud computing in 2020, smart homes will enter the fast lane. The integration of these technologies is just around the corner. A brain that can “think” and “make decisions” to transform passive feedback to active response and realizes a real human-computer interaction experience is on the way. Voice interaction will gradually replace traditional apps and touch control to realize self-learning and control of the systems. Visual processing and gesture recognition will bring more powerful interaction capabilities for smart homes. It can also provide users with personalized life services through the collection and analysis of user behavior data, so that home life will become safe, comfortable, energy-saving, efficient, and convenient.

2.3.4. The main players of smart homes industry in China

As China's smart home industry is gradually moving from the single smart product stage to the whole house intelligence stage, three business camps have differentiated, they are traditional Internet giants such as BAT (Baidu, Alibaba, Tencent), smartphone manufacturers such as Xiaomi and Huawei, and traditional home appliance companies have successively deployed the smart home industry.

The first is the Internet camp represented by Baidu, Alibaba, and Tencent. Backed by the natural flow of the Internet and huge capital, BAT has natural platform ecological attributes. The research and development of small home appliances are more time-saving, labor-saving, and money-saving for the Internet company. They use smart speakers as the entry point, such as Baidu's "Xiaodu", Ali's "Tmall Elf", and Tencent's "Tingting". Currently, Chinese IT giants are actively deploying their smart homes AIoT (AI+IoT) ecosystem via their advantages in smart speakers’ market share. In early 2020, Alibaba upgraded the Tmall Genie business to an independent business department. The Tmall Genie department held a 2020 spring conference and proposed the "Double Hundred Plan" in May. They announced that Alibaba would invest tens of billions to build content, services, and the AIoT ecosystem and further consolidate the growth soil of smart speakers. They will create hundreds of smart home devices to accelerate the explosion of smart industry with the integration of Alibaba Cloud’s IoT resources. Relying on Internet thinking and design, supply chain, brand, and channel sales capabilities, Xiaomi has accumulated a large quantity of user base, numerous equipment, massive data, and application scenarios to build its own AIoT ecosystem. Baidu has the world's leading ABC (Artificial Intelligence, Big Data, Cloud Computing) and IoT technology. The guarantee of hard power allows Baidu to quickly gain the right of speech in the smart speaker industry and enter the first echelon. In 2019, Baidu focused on the screen speaker layout. With the excellent technical foundation, high-quality hardware products, and rich content resources, it quickly grabbed half of the screen speakers and maintains its leading role until now. By 2020, Baidu successively released three-screen speakers, continuing to consolidate its leading position.

The second is the smartphone manufacturers camp, represented by Xiaomi and Huawei, such as Xiaomi’s "Xiao Ai" and Huawei’s "Xiaoyi". Xiaomi and Huawei, both of which were born in hardware, have formed a parallel business model of smart furniture and mobile phone business. Take Huawei as an example. In December 2020, Huawei held a new product launch conference for the whole house smart and smart screen, and officially released Huawei's smart home strategy and whole house smart solutions. Unlike other smart home manufacturers, Huawei did not design its own "central control screen", instead it used its own Huawei mobile phones to achieve central control. From air-conditioning TVs to smart door locks to cameras, the smartphone camp has created a rich industry field for smart homes.

The third is the traditional home appliance industry camp, represented by Haier, Midea, and Gree. Traditional home appliance giants such as Haier tend to establish a full-product model for smart homes, enhance brand effects, increase customer stickiness, and develop towards platformization, ecoligization, and scalization. Home appliance companies will give priority to large home appliances, such as TVs, refrigerators, air conditioners, and so on. For example, Gree's smart home products first launched smart air conditioners, and Midea's smart home products first launched smart refrigerators. These home appliance companies have invested a lot of time, money, and manpower in the research and development of large home appliances and have accumulated rich experience.

In addition to the above three camps, traditional electrical and controller manufacturers such as ABB, Legrand, Philips, and Op Lighting are also involved in the smart home industry; so do real estate companies in China such as Vanke, Evergrande, and Country Garden; China Mobile, China Telecom, China Unicom, and other communications manufacturers, as well as emerging smart home manufacturers such as Tuya Smart, Oribo, Bolian, and Green Rice. But compared to the market share of the three main camps, the market performance of these camps is not optimistic.

2.3.5 The research status of smart homes for elderly

The dual decline of physical functions and social functions has caused the physical and psychological, and cognitive disconnection of the elderly from the outside world. Thus, how to apply modern technology to help the elderly rebuild "connectivity" and create an independent, safe, happy home environment is a question that all the smart home researchers and developers should take into consideration in the future. The market maturity and popularity of smart homes are still low [8], and the aging adoption trend of the smart home industry is not obvious [9]. However, there is no doubt that a smart home would have a prosperous future and provide an effective solution for the global challenges of an aging society [10]. At present, many developed countries are already exploring the application of smart homes in dealing with the aging challenges, such as the United States, the United Kingdom, France, Italy, Japan, South Korea, etc. [11]. Many projects are in progress, with funding from international organizations and local governments.

In the United States, the "Aging in place" project at the University of Missouri in Colombia focuses on offering elderly long-term healthcare services in the home environment due to their choices [12]. Another project at MIT, called "The house of the future", conducts qualitative and quantitative studies on the relationship of the elderly group with their living environment factors and builds a user model based on updating the machine learning data set [13]. Moreover, there is a smart home system called "ACHE" in boulder, which aims to optimize the usage of energy resources by realizing intelligent control of temperature, heating, and lighting with respecting the lifestyle and habits of its residents [14]. What is more, "GatorTech Smart House" in Florida, developed by Helal et al., equipped the home components including entrance door, bathroom, floor, mailbox, etc. with sensors and actuators and connected them into the online platform to try to provide a comfortable and safe home environment for the elderly [15].

In Europe, Gloucester's Smart House project funding by the UK government aims to help the elderly suffering from dementia. The majority of items in the house are under continuous monitoring via sensors [16]. Another project called "The ENABLE" also focuses on the subject with moderate dementia and provides assistive technology to improve their quality of life [17,18]. Moreover, "CarerNet", a project in the UK, proposes the concept of "hospital at home" and deploys telemedicine services for older adults, including emergency response, community health information, real-time monitoring, etc. [19]. In Netherland, a smart home system has been built to learn residents habits and make decisions by itself according to the subjects' behavior pattern and daily routine, and it can also measure the daily physiological signs such as blood pressure, blood sugar, mean arterial pressure, arrhythmia, lung capacity, body weight, body temperature, and body fat. The main purpose of this project is to promote the communication of seniors, caregivers, and service providers [20].

In some Asian countries, like Japan, smart homes usually apply assistive technologies to create a smart and comfortable environment for older adults to live at home and improve their quality of life. There are 13 smart home examples called "Welfare Techno-Houses (WTH)" built by The Japanese Ministry of International Trade and Industry [21,22]. In Tokyo, Andoh et al. have developed a system based on resident vital physical signs analysis, including breathing, heart rate, body motion, etc., to monitor the sleeping status of seniors [23]. In Nara, Masuda et al. have designed a monitoring system to provide elderly physical data and daily life information for rehabilitation therapists [24]. Moreover, a smart home, designed by Dr. Matsuoka in Osaka, inserts 167 sensors in a home environment, including home appliances like refrigerator, TV set, rice cooker, air conditioning, and home furniture to detect the elderly's activities and realize intelligent adjustment and control [25].

The discussion above is a part of typical smart home examples, and there are still plenty of other projects and research. However, to sum up, the majority of existing projects and research are mainly concentrated in the following five aspects. First, home automation. It aims to help people improve the comfort of the home environment. Second, energy usage optimization. It is to continuously monitor important parameters of the home environment and optimize the energy usage to realize energy saving. Third, emergency and accident prevention. This aspect is to use sensors networks to monitor and predict home life and environmental hazards to reduce property and personal accidents. Fourth, healthcare. This function is mainly to help seniors cope with the reduction of physical functions through intelligent technology, like perception and cognitive abilities. Fifth, health management and medical rehabilitation. This aspect is to monitor the elderly's mobility and physiological parameters through wearable biomedical sensors to provide health management and rehabilitation treatment.

It is true that the use of intelligent devices and sensor technology is the foundation of a smart home, and health and safety issues are one of the most concerned aspects of the elderly group. However, with unprecedented developments on the medical level, there is an increasing number of healthy elders, and this group accounts for a large proportion of the whole elderly population [26]. In terms of spiritual and emotional life, their needs are no different from those of normal people. Physiology refers to the life activity of the biological organism and the function of each organ. Psychology is related to the process and result of sorting out the inner symbol activities of people. Specifically, it refers to biological manifestations of subjective reflection of the objective material world, called psychological phenomena, including psychological processes and psychological characteristics. Human psychological activities have a process of occurrence, development, and disappearance. When people are active, they understand things in the external world through various senses and think about the causality of things through brain activities, accompanied by emotional experiences such as joy, anger, sorrow, and fear. This reflects the whole process of a series of psychological phenomena is the psychological process. According to its nature, it can be divided into three aspects, namely the cognitive process, the emotional process, and the will process, referred to as knowledge, affection, and intention. Psychological choices are perceptual, and physical choices are organic.

Older adults want an independent, safe, and decent life. They also need recognition and respect from the external world rather than being treated as a vulnerable group who needs additional help [27]. At the same time, the mental status of the elderly plays an important role in their physical health. Even before serious diseases, the psychological state exerts a significant effect on their health status [28]. So the research and developers of a smart home for seniors only laying emphasis on the technical part or home environment or healthcare indeed somehow loses the essence of elderly needs. Because these concerns mostly stay at the survival level and ignore the psychological needs and spiritual life of the elderly group. Some scholars have also noticed related issues and put forward that smart homes should promote the socialization interaction of older adults and help them deal with the problem of isolation [11,29,30], but they fail to put forward the concept of creating a smart home for all-around happiness for the elderly and lack the in-depth exploration of relevant system evaluation and construction.

2.4 Technology acceptance model

1967, the Theory of Reasoned Action (TRA), a general theory of behavior prediction, was first introduced by Fishbein and Icek Ajzen [31]. They believe that behavioral beliefs determine people's attitudes, normative beliefs determine subjective norms, and attitudes and subjective norms together determine behavioral intention, which in turn affects actual behavior. In 1985, Icek Ajzen found that people have control beliefs in the process of behavioral decision-making. He improved the theory of TRA by adding Perceived behavioral control elements and proposed the Theory of Planned Action (TPB)[32]. He believes that people’s decision-making behavior includes consideration of behavioral risks, and whether the perceived risk is controlled stays an important factor affecting people’s behavioral intentions and actual behavior. In TPB, he introduced the concept of “perceived” and pointed out the subjectivity of people's decision-making behavior. In 1989, Davis applied TRA and TPB to the field of information systems to explain users' acceptance of information technology and proposed the Technology Acceptance Model (TAM) [33]. In TAM, he takes system design feature variables as external variables as the initial factors for people to decide whether to use the information system, external variables directly determines the perceived ease of use, and then these two variables together determine the perceived usefulness, the perceived usefulness and perceived ease of use together determine people's attitude toward using, which in turn affects people's behavioral intention to use, the behavioral intention to use ultimately determines the actual system use. The Innovation Diffusion Theory (IDT) was proposed by the American scholar Everett M. Rogers in 1962 about persuading people to accept new ideas, new things, and new products through the media, which focuses on new technologies and social behaviors and reveals the process of the spread of new technologies in society [34]. Social Cognitive Theory (SCT) start as Social Learning Theory (SLT) in the 1960s and developed into SCT in 1986 by Albert Bandura, which believes that learning takes place in a social environment, where personal factors, environmental factors, and behaviors have dynamic and mutual interactions

[35]. It assumes that users acquire and maintain behaviors while considering the social environment of their developing behaviors and highlights the concept of self-efficacy. The Motivation Model (MM) was used by Davis et al. to study the adoption and use of Information Communication Technology (ICT) in 1992 [36]. Thompson et al. proposed the Model of Personal Computer Utilization (MPCU) in 1991 to predict users' personal computer usage behavior [37].

To sum up, the existing Technology Acceptance Model (TAM) has provided valuable references for the TAM research of smart homes for future elders, but there is a gap in current value evaluation and risk identification of emerging technology for the elderly group. The core value needs and typical characteristics of the aging group have not been well considered in existing researches. Moreover, there is the limitation of the conventional technology acceptance model, which takes the perceived usefulness and perceived ease of use as the core variables. Nowadays, due to the development of information communication technology (ICT), customers could form recognition and perceptions about certain products and services via multi-channels and a variety of ways, like offline experience, online information, and comments, mass media, broadcasting, pictures, radios, videos, etc., and then decide whether to purchase and use certain products and services. Moreover, users' requirements are diverse and complex, which are far more beyond the functional demand. Also, for the integrated system platform like smart home, it involves complicated problems like privacy, security, and ethical issues, which are out of the range of usefulness and ease of use. Thus, the traditional technology acceptance model could not respond to the diverse needs and technology harmfulness of complex, intelligent systems platforms.

2.5 Wellbeing theory and measurement

2.5.1 Subjective wellbeing and scale

Positive psychology is one of the latest branches of psychology. It mainly conducts research and proposes theories on the power and virtue to make individuals and communities thrive [38]. The theme of positive psychology is "happiness". Happiness is a seemingly simple but extremely complex concept. It is also a goal that humans have striven to own and pursue since ancient times. Subjective wellbeing (SWB), as one of the important research fields of Positive Psychology [39], has received extensive attention from researchers. It is an individual's overall evaluation of his own quality of life, and it is one of the important indicators of the individual's mental health level [40]. It has two main components: life satisfaction and emotional experience, including positive and negative emotions [41]. Since the concept of subjective wellbeing was proposed, related scholars have paid close attention to the standardized measurement of subjective wellbeing and proposed a series of measurement indicators. Diener has developed a subjective wellbeing scale, which includes two parts, namely the positive and negative affect scale (PANAS) and the Satisfaction with life scale (SWLS), which has been widely adopted [42]. Other scales, like the Index of Well-Being (IWB) compiled by Campbell, includes two parts which are the satisfaction of life and perceived stress [43]. Memorial University of Newfoundland Scale of Happiness(MUNSH), which is applicable to the elderly and has been widely used [44].

2.5.2 PERMA-V model

For the existing research of wellbeing, the majority of them only provide the basic concept definition, dimensions categories, or measurement scale of wellbeing, which is far from the comprehensive way. The PERMA model is a model of human psychological wellbeing, which is considered to be the most comprehensive framework of “the good life”, and is the foundation of positive psychology in science and practice. Martin Seligman, the "father of positive psychology" in the book "Flourish: A visionary new understanding of happiness and wellbeing" proposed it. As shown in figure 1.1, it includes five aspects: P (positive emotion), E (engagement), R (relationship), M (meaning) and A (accomplishment) [45]. In 2011, Martin Seligman added a new dimension “V(Vitality)”, and points out that the overall happiness of individual must be the comprehensive development, full experience, and display in these six dimensions. In this model, wellbeing is understood as being more than experiencing positive emotions and feeling happy. The new dimension has given the physical foundation for the other dimensions and makes the model presents a much stronger explanation about the all-around wellbeing of human beings.

The specific contents are as follows:

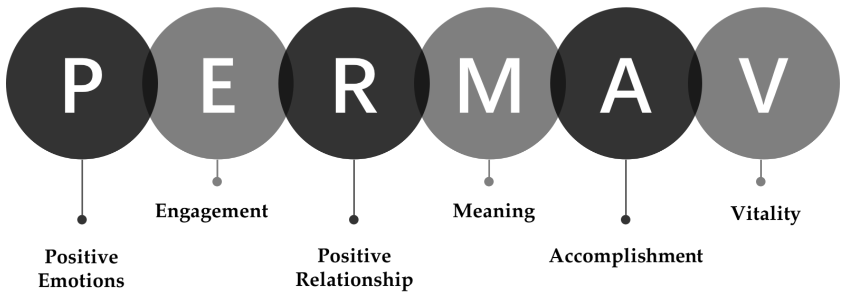

Figure 2.1. The positive psychology PERMAV model

- **Positive emotions:** Positive emotions are the foundation of happiness theory, which refers to the subjective feelings that can make us happy, warm, and comfortable. Life, which can successfully show these attributes, is called a pleasant life. Positive emotions have a broadening effect on our thoughts and actions. They allow us to discard automatic responses and instead look for creative, flexible, and unpredictable new ways of thinking and acting. Positive emotions are strongly correlated with both resilience and wellbeing. Emotions are contagious, and we know positive emotional states are conducive to building strong relationships.
- **Engagement:** Engagement is a state when a person really enjoys and values doing something. He will devote himself to the moment and concentrate on doing it. In positive psychology, this state of involvement is called "flow". Engagement occurs when we employ our skills and strengths to meet a challenge. When we are engaged, we focus our attention on a task and are at one with the moment.
- **Relationship:** Positive relationships include the forms of regular contact, communication, activities, mutual care, help, appreciation, and gratitude. These positive relationships allow individuals to be listened to, comforted, encouraged and reminded so that they have the ability to face difficulties and adversities. Relationships are fundamental to wellbeing. The experiences that contribute to wellbeing are often amplified through our relationships, for example, great joy, meaning, laughter, a feeling of belonging, and pride in accomplishment. Connections to others can give life purpose and meaning.

- **Meaning:** Meaning is a personal sense of belonging, and this thing brings value beyond the individual. If people want to be happy, they must feel that their life is meaningful, worthwhile, and valuable. Having a sense of meaning and purpose occurs when we serve something bigger than ourselves. We know that cultivating connections to others, identifying and working toward a purpose, telling stories about our place in the world, and making contributions beyond ourselves can immeasurably deepen our lives and our wellbeing.
- **Achievement:** A sense of accomplishment is the feeling of being happy or successful in what a person has done when they complete or finish something. Human beings have a basic need to feel they are growing and making progress in life.
- **Vitality:** Research shows us that vitality is integral to our wellbeing. Our ability to sleep deeply, eat well, and exercise regularly has a significant impact on all other elements of wellbeing. Maintaining physical vitality is essential for building resilience and bouncing back through adversity and challenge.

Smart homes will have huge market prospects in China and will undoubtedly change our future life style in this artificial intelligent era. It presents infinite potential in dealing with the aging challenges and help the elderly aging in place and live an independent, safe, healthy, and happy life after retirement. Despite the optimistic expectation of future market growth, the development of whole house intelligence of smart home is still in its early and realization phase. The products and services are yet far from mass-market adoption[5]. The essential problem is that the existing smart home products and services for older adults could not meet their core value demand, and the application of technology and service delivery have not been able to eliminate or reduce their worries and perceived risks. Moreover, with regarding to technology acceptance and adoption, there is limitation of the conventional technology acceptance model, which taking the perceived usefulness and perceived ease of use as the core variables and could not respond to the diverse needs and technology harmfulness of complex, intelligent systems platforms like smart homes. Thus, the research of the scale development of the perceived value and perceived risk of smart homes for the elderly, and the construction of a new technology acceptance model based on these two core variables which reflect the core value and typical risks of smart homes are necessary and urgent. Home is the place where people spend the longest time in their lives. At the same time, compared to a single product or service, smart home is the integration of numerous products and intelligent service systems. This combination determines that smart homes have functions beyond the conventional single product or service and provide the possibility and huge potential of shaping all-around wellbeing for the elderly in home life. The PERMA-V model is a model of human wellbeing, which is considered to be the most comprehensive framework of "the good life" indicating the structure of all-around wellbeing of the individual. In this study, the author intends to integrate this meaningful theory with the application of smart technology to construct all-around happiness home environment for older adults, which remains an innovative cross-field integration and provides a new approach for the exploration of how smart technology could sculpt wellbeing for aging group.

Reference

1. Melyani; Meyliana; Prabowo, H.; Hidayanto, A.N.; Gaol, F.L. Smart Home Component using Orange Technology for Elderly people: A Systematic Literature. In Proceedings of the 2018 Indonesian Association for Pattern Recognition International Conference (INAPR), 7-8 Sept. 2018, 2018; pp. 166-171.
2. Chapman, K.; McCartney, K. Smart homes for people with restricted mobility. Property management 2002.
3. Chen, S.-Y.; Chang, S.-F. A review of Smart Living space development in a cloud computing network environment. Computer-Aided Design and Applications 2009, 6, 513-527.
4. Cimperman, M.; Brenčič, M.M.; Trkman, P.; Stanonik, M.d.L. Older adults' perceptions of home telehealth services. Telemedicine and e-Health 2013, 19, 786-790.
5. Hong, A.; Nam, C.; Kim, S. What will be the possible barriers to consumers’ adoption of smart home services? Telecommunications Policy 2020, 44, doi:10.1016/j.telpol.2019.101867.
6. Neville, S. Eavesmining: A critical audit of the Amazon Echo and Alexa conditions of use. Surveillance & Society 2020, 18, 343-356.
7. All View Cloud: Chinese smart speaker market summary in the first half of 2020. Available online: http://finance.sina.com.cn/tech/2020-12-14/doc-iiznctke6373527.shtml (accessed on 4th, March).
8. Balta-Ozkan, N.; Davidson, R.; Bicket, M.; Whitmarsh, L. Social barriers to the adoption of smart homes. Energy Policy 2013, 63, 363-374.
9. Pal, D.; Papasratorn, B.; Chutimaskul, W.; Funilkul, S. Embracing the smart-home revolution in Asia by the elderly: An end-user negative perception modeling. IEEE Access 2019, 7, 38535-38549.
10. Chan, M.; Campo, E.; Estève, D.; Fourniols, J.-Y. Smart homes—current features and future perspectives. Maturitas 2009, 64, 90-97.
11. Chan, M.; Estève, D.; Escriba, C.; Campo, E. A review of smart homes—Present state and future challenges. Computer methods and programs in biomedicine 2008, 91, 55-81.
12. Rantz, M.J.; Marek, K.D.; Aud, M.; Tyrer, H.W.; Skubic, M.; Demiris, G.; Hussam, A. A technology and nursing collaboration to help older adults age in place. Nursing Outlook 2005, 53, 40-45.
13. Intille, S.S. Designing a home of the future. IEEE pervasive computing 2002, 1, 76-82.
14. Mozer, M.C. The neural network house: An environment hat adapts to its inhabitants. In Proceedings of the Proc. AAAI Spring Symp. Intelligent Environments, 1998.
15. Helal, S.; Mann, W.; El-Zabadani, H.; King, J.; Kaddoura, Y.; Jansen, E. The gator tech smart house: A programmable pervasive space. Computer 2005, 38, 50-60.
16. Orpwood, R.; Adlam, T.; Gibbs, C.; Hagan, S. User-centred design of support devices for people with dementia for use in a smart house. Assistive Technology-Added Value to the Quality of Life, IOS Press 2001, 314-318.
17. Hagen, I.; Holthe, T.; Duff, P.; Cahill, S.; Gilliard, J.; Orpwood, R.; Topo, P.; Bjorbe, S. Can assistive technology enable people with dementia? Assistive Technology-Added Value to the Quality of Life, IOS Press 2001, 42-47.
18. Adlam, T.; Faulkner, R.; Orpwood, R.; Jones, K.; Macijauskiene, J.; Budraitiene, A. The

installation and support of internationally distributed equipment for people with dementia. IEEE Transactions on Information Technology in Biomedicine 2004, 8, 253-257.

19. Williams, G.; Doughty, K.; Bradley, D.A. A systems approach to achieving CarerNet-an integrated and intelligent telecare system. IEEE transactions on Information Technology in Biomedicine 1998, 2, 1-9.
20. Vermeulen, C.; van Berlo, A. A model house as platform for information exchange on housing. Studies in health technology and informatics 1998, 48, 337-339.
21. Yamaguchi, A.; Ogawa, M.; Tamura, T.; Togawa, T. Monitoring behavior in the home using positioning sensors. In Proceedings of the Proceedings of the 20th Annual International Conference of the IEEE Engineering in Medicine and Biology Society. Vol. 20 Biomedical Engineering Towards the Year 2000 and Beyond (Cat. No. 98CH36286), 1998; pp. 1977-1979.
22. Tamura, T.; Ogawa, M.; Yoda, M.; Togawa, T. Fully automated health monitoring system in the home. IEEJ Transactions on Electronics, Information and Systems 1998, 118, 993-998.
23. Andoh, H.; Watanabe, K.; Nakamura, T.; Takasu, I. Network health monitoring system in the sleep. In Proceedings of the SICE 2004 Annual Conference, 2004; pp. 1421-1424.
24. Masuda, Y.; Sekimoto, M.; Nambu, M.; Higashi, Y.; Fujimoto, T.; Chihara, K.; Tamura, Y. An unconstrained monitoring system for home rehabilitation. IEEE engineering in medicine and biology magazine 2005, 24, 43-47.
25. Let, X. Pattern classification. 2005.
26. Beard, J.R.; Officer, A.; De Carvalho, I.A.; Sadana, R.; Pot, A.M.; Michel, J.-P.; Lloyd-Sherlock, P.; Epping-Jordan, J.E.; Peeters, G.G.; Mahanani, W.R. The World report on ageing and health: a policy framework for healthy ageing. The lancet 2016, 387, 2145-2154.
27. Howell, S.C. The potential environment: Home, technology, and future aging. Experimental aging research 1994, 20, 285-290.
28. McKee, K.J.; Wilson, F.; Chung, M.C.; Hinchliff, S.; Goudie, F.; Elford, H.; Mitchell, C. Reminiscence, regrets and activity in older people in residential care: Associations with psychological health. British Journal of Clinical Psychology 2005, 44, 543-561.
29. Percival, J.; Hanson, J. Big brother or brave new world? Telecare and its implications for older people's independence and social inclusion. Critical Social Policy 2006, 26, 888-909.
30. Demiris, G.; Rantz, M.J.; Aud, M.A.; Marek, K.D.; Tyrer, H.W.; Skubic, M.; Hussam, A.A. Older adults' attitudes towards and perceptions of 'smart home'technologies: a pilot study. Medical informatics and the Internet in medicine 2004, 29, 87-94.
31. Fishbein, M. Reasoned Action, Theory of. In The International Encyclopedia of Communication; 2008.
32. Ajzen, I. From intentions to actions: A theory of planned behavior. In Action control; Springer: 1985; pp. 11-39.
33. Davis, F.D. Perceived usefulness, perceived ease of use, and user acceptance of information technology. MIS quarterly 1989, 319-340.
34. Wani, T.A.; Ali, S. Innovation diffusion theory. Journal of general management research 2015, 3, 101-118.
35. Schunk, D.H. Social cognitive theory and self-regulated learning. In Self-regulated

learning and academic achievement; Springer: 1989; pp. 83-110.
36. Davis, F.D.; Bagozzi, R.P.; Warshaw, P.R. Extrinsic and intrinsic motivation to use computers in the workplace 1. Journal of applied social psychology 1992, 22, 1111-1132.
37. Thompson, R.L.; Higgins, C.A.; Howell, J.M. Personal computing: Toward a conceptual model of utilization. MIS quarterly 1991, 125-143.
38. Compton, W.C. Introduction to Positive Psychology; Thomson Wadsworth: 2005.
39. Cummins, R.A. Positive psychology and subjective wellbeing homeostasis: A critical examination of congruence. In A positive psychology perspective on quality of life; Springer: 2012; pp. 67-86.
40. Diener, E.; Suh, E.M.; Lucas, R.E.; Smith, H.L. Subjective wellbeing: Three decades of progress. Psychological bulletin 1999, 125, 276.
41. Diener, E.; Emmons, R.A. The independence of positive and negative affect. Journal of personality and social psychology 1984, 47, 1105.
42. Diener, E.; Emmons, R.A.; Larsen, R.J.; Griffin, S. The satisfaction with life scale. Journal of personality assessment 1985, 49, 71-75.
43. Campbell, A. Subjective measures of wellbeing. American psychologist 1976, 31, 117.
44. Kozma, A.; Stones, M. The measurement of happiness: Development of the Memorial University of Newfoundland Scale of Happiness (MUNSH). Journal of Gerontology 1980, 35, 906-912.
45. Seligman, M.E. Flourish: A visionary new understanding of happiness and wellbeing; Simon and Schuster: 2012.

Chapter 3
The characteristics of the elderly

Chapter 3 The characteristics of the elderly

3.1 Research purpose

The primary purpose of this chapter is to discuss the characteristics of older adults, which mainly contains the physical characteristics, psychological characteristics, cognitive characteristics, and consumption characteristics. The summary of the characteristics of older adults could provide the analysis basis for the dimension extraction and item generation of perceived value and perceived risk of smart homes for the elderly.

3.2 Research method

This chapter mainly adopts two kinds of research methods. The first is literature review to gain the relevant record, description, and analysis of the elders' characteristics. The second is inductive analysis to summarize the relevant features of the elderly into four aspects, namely physical, psychological, cognitive, and consumption characteristics.

3.3 The characteristics of elderly

With the increase of age, the physical and social functions of the elderly will unavoidably decline and decay. Table 1 shows the aging age of the principal organs of the human body, which is compiled and summarized by the author based on literature review and materials scanning. From the table, we can see the human body aging laws and regulations, which could support further characteristic analysis of older adults.

Table 1. The aging age of human organs

The aging age of human organs								
Brain	Lung	Skin	Muscle	Breast	Bone	Fertility	Heart	Eyes
20	20	25	30	35	35	35	40	40
Teeth	Prostate	Kidney	Hearing	Intestine	Taste& Smell	Bladder	Sound Gland	Liver
40	50	50	55	55	60	65	65	70

3.3.1 Physical characteristics

The human body comprises the following nine significant systems: motor system, nervous system, endocrine system, circulatory system, respiratory system, digestive system, urinary system, reproductive system, and immune system [1]. The improvement of the quality of life and the level of medical care has led to the continuous extension of the average life expectancy of mankind [2]. The health status of the elderly in China has generally entered a stage where chronic diseases and degenerative diseases are predominant. Most of them are healthy and energetic older adults who have the ability to take care of themselves and do not need special care and concerns within a certain age period [3]. The author summarizes the typical degradation of the elderly in physical aspect as following：

- **Degeneration of sensory system:** Degeneration of the nervous system could directly lead to the degradation of the elderly's sensory system, which is mainly reflected in the aspects of vision, hearing, taste, smell, and touch, and will affect external stimuli and information acceptance, manifested as unresponsiveness, especially hearing and vision. It can lead to severe life disorders.

- **Degeneration of skeletal and muscle system:** For the elderly group, the decrease of calcium in bone and bone density may easily multiple fractures. The muscle tissue of the ordinary human body begins to decrease from about 50 years old. The process accelerates significantly after 60 years old, which leading to muscle relaxation and may turn into amyotrophic lateral sclerosis (ALS) in severe cases. It could dramatically affect the daily life of older adults, such as being unable to perform high-intensity exercise. And if the situation getting worse, it may bring walking obstacles in daily life.
- **Degeneration of cardiopulmonary system:** Because of the decline of the endocrine system, female ovaries or testes begin to reduce the quantity of hormones that will directly affect the nervous system works. During this period, people often experience chest tightness, shortness of breath, palpitations, shortness of breath, dizziness, tinnitus, irregular heart rate, and even cardiovascular and cerebrovascular diseases. Deterioration of the heart and lungs could cause respiratory and circulatory problems, like heart disease, hypertension, and hyperglycemia, which are very common in the elderly group.
- **High incidence of chronic disease:** Chronic diseases are closely related to the individual's lifestyle. Multiple stress from work and life in middle age and former life is one of the important reasons leading to the high incidence of chronic diseases for the elderly. Being lack of exercise, unhealthy eating habits could also be the causes. Over time, an unhealthy lifestyle will cause declines in the body's immune system, eventually leading to various chronic diseases.

3.3.2 Psychological characteristics

In China, after retirement, the social scope of seniors is usually limited to the family and surrounding communities. At the same time, most of their children are busy with their works and live away in another city, so they could not give enough companionship and concern to their parents. This situation may easily cause some psychological diseases ignored by their children, even themselves. Moreover, physical function declines and chronic diseases of the elderly could also bring the elderly different degrees of psychological changes. Over time, it may lead to severe psychological diseases and affect physical health. The parents of the first one-child generation in China have or will soon enter the group of older adults [4]. With the acceleration of the urbanization process, their children usually go to progressive cities and regions to receive a higher quality education and pursue their occupation career, which will make the older generation live alone in their house or hometown [5]. In 2020, there will be more than 118 million older adults living alone and in empty nests in China [6]. The intense emotional dependence on children and the reunion desire with the extended family make the elderly group have a stronger sense of loneliness [7]. The weakening of traditional family support and the rapid development of social media has given rise to the need for social networking, entertainment, companionship, and spiritual comfort for the elderly. The author summarizes the typical psychological characteristics of the Chinese elderly as following:

- **Loneliness and depression:** Most older adults in China live a busy life before retirement, moving between work and family all day long. It is hard for them to feel lonely because of the solid spiritual pursuit of career success and value realization. However, after retirement, they are easy to lose their life goals and future plan. Some seniors could easily get depression. As time goes by, such negative feelings of loneliness and depression will lead to a poor mental state of the elderly and invoke suspicious and anxious emotions. For instance, the phenomenon of "empty-nest elderly" is a severe problem in China. No family members are accompanying them, leading their sense of security to drop and loneliness to rise.

- **Inferiority and frustration:** Due to the decline of physical and cognitive functions of the elderly, many inconveniences and mistakes could appear in life, such as improper handling of things, difficulty in accepting new things, the pain of illness, etc. These situations are very likely to bring negative emotions of inferiority and self-criticism to seniors. They will be more sensitive and easily get frustrated because of their powerlessness to reality and aging.
- **Degeneration of cardiopulmonary system:** The secretion quantity of hormones will reduce with the aging process of the endocrine system, including ovaries and testes, which will directly affect the nervous system. During this period, people often experience chest tightness, shortness of breath, palpitations, shortness of breath, dizziness, tinnitus, irregular heart rate, and even cardiovascular and cerebrovascular diseases. Deterioration of the heart and lungs has caused respiratory and circulatory problems in older people. Conditions such as respiratory diseases and heart disease, as well as hypertension and hyperglycemia, are very common in the elderly.
- **Menopause symptoms:** After entering menopause, both men's and women's physical and psychological states will change significantly. Poor mood, irritability, nervousness, anxiety, insomnia, and sentimentality are often presenting. Older adults are eager to receive attention and respect in old age and reducing the psychological gap resulting from retirement. Therefore, it is essential to pay attention to the mental health of retired elderly, enrich their spiritual and cultural life, and help them expand their social circles.

3.3.3 Cognitive characteristics

With the aging process, brain cells begin to decrease, nervous system begins to shrink, information delivery and nerve conduction efficiency will considerably be slowed down compared to young people. The cognitive characteristics of the elderly are mainly reflected in cognitive aging and cognitive impairment.

- **Cognitive aging:** The characteristics of cognitive aging mainly manifest in a slower motion and central nervous processing speed, reduced working memory, decreased ability to suppress the effects of irrelevant stimuli, and increased physical disharmony. It includes intelligence decline, thinking ability decline, memory decline, responsiveness decline, learning and operating ability decline. Because of these facts, most older people have a weaker ability to perceive and accept new things, making them spend more time than the young group to learn a new operation or master a new skill.
- **Cognitive impairment:** Cognitive impairment could be divided into mild degree and severe degree. Studies have shown that there is a great chance that mild cognitive impairment could turn into Alzheimer's disease [8]. Alzheimer's disease is a degenerative neurological disorder with a more insidious, progressive development [9]. Cognitive impairment, memory impairment, visual impairment, speech loss, executive disability,

and personality change are all clinical symptoms [10]. The etiology has not been identified so far. Professor Reidrey of the Alzheimer's Research Fund Committee in the UK said: "Researchers believe that the hidden dangers of Alzheimer's disease begin in middle age. Maintaining an active and healthy lifestyle, such as keeping a good diet and doing a regular examination of blood pressure and cholesterol, can significantly reduce the prevalence of Alzheimer's disease [11].

3.3.4 Consumption characteristics

Concerning the consumption characteristics of the elderly, there are both positive and negative aspects. The following gives a discussion in detail:

- **Consumption disadvantages due to physical and psychological decline:** The judgment ability and logical thinking ability of the elderly all decrease with the increase of age[12]. In terms of consumption characteristics, the consumption behaviors of the elderly are easily affected by pragmatic, anxiety, herd, compensation, and profit-seeking psychology. When encountering with rights violation situation, their protection awareness is weak[13].
- **Diverse consumption demands:** The new elders who have just retired generally are in good health, and there is no significant difference in their demands compared with the young and middle-aged. In addition to essential nutrition and medical treatment, they advocate freedom and pursue comfort. They have strong enthusiasm for colorful and abundant life, such as travel, sports, fashion, beauty, fitness, food, leisure, entertainment, skills, and hobbies[14].
- **Pursue high-quality life:** With the continuous improvement of China's economic, medical standards, and pension assurance, Chinese new elders often have a certain amount of savings and have formed a stable lifestyle and modern consumption habits. They are willing to consume to improve their quality of life and strengthen their feeling of happiness and fulfillment [15].
- **Closer connection with the Internet:** Chinese new elders shows a high degree of acceptance of the Internet and proficient use of electronic products, which profoundly reshapes their consumption patterns. The big data released by JD.com shows that electronic products such as smartphones and tablets are among the top search keywords for elders. The use of mobile terminals, online payment, e-commerce platforms were once the "patent" of young people. But, now, there are numerous Chinese elders and middle-aged people who can operate them proficiently. At present, the number of Internet users over 60 in China has exceeded 400 million; more than 60% of the elderly can use WeChat, Alipay, and other mobile terminals for consumption. According to data from Alibaba Group, online shoppers over the age of 50 in China presents a colossal base. The number is nearly 30 million on Taobao and Tmall. Many older adults choose online platforms to buy food and daily necessities, make orders and reservations. It is easy and convenient, which provides great help for older adults with poor physical mobility. It can be seen that more and more middle-aged and older adults are integrating into the Internet environment in China. The weakened living ability and social isolation of the elderly need the assistance of intelligent products and services. They are even more in need of intelligent technology than the young groups [16].

According to the characteristic analysis of the elderly from physical, psychological, cognitive and consumption aspects, some fact and conclusion can be obtained. On one hand, comparing with the general people or youth group, the elderly present totally different characteristics with the increase of age, which including the degeneration of sensory system, skeletal and muscle system, cardiopulmonary system as well as high incidence of chronic disease in physical aspect, loneliness and depression, inferiority and frustration, degeneration of cardiopulmonary system, menopause symptoms in psychological aspect; cognitive aging and cognitive impairment in cognitive part, etc. Thus, the development and design of smart homes for the elderly should take these characteristics into consideration, compensate for their weaken ability and try to reduce their perceived risks as much as possible. On the other hand, the diverse consumption demand, pursuit for high quality life and close connection with internet of the elderly, provide the foundation and feasibility to apply various innovative technology in the home environment to satisfy their diverse value demand. What's more, the conventional smart homes for the elderly usually focus on their physical demand. Concerning the psychological and cognitive perspectives, there are also plenty of ways in which we can apply to meet their related value demand through smart home technology. Thus, the goal of constructing overall happiness for the elderly via smart homes should be given emphasis and put on the agenda. To sum up, the analysis of the characteristics of the elderly could help the research to grasp the value demands, risk perception, and consumption preference of Chinese elderly and provide the foundation for the generation, refinements, and adjustment of the measurement items of related perceived value scale and perceived risk scale. It could also further contribute to the construction of the technology acceptance model of smart homes for the elderly in the following research process.

References

1. Forbes, G.B. Human body composition: growth, aging, nutrition, and activity; Springer Science & Business Media: 2012.
2. Lubitz, J.; Cai, L.; Kramarow, E.; Lentzner, H. Health, life expectancy, and health care spending among the elderly. New England Journal of Medicine 2003, 349, 1048-1055.
3. Yabukita, H.; Miyazaki, R.; Nomoto, K.; Ishii, K.; Ogura, M.; Yagi, M.; Yonei, Y. Characteristics of physical functions in elderly people requiring support. Anti-Aging Medicine 2013, 10, 16-20.
4. Wang, S.; Zhao, Z. Parent Care in the First One-child Generation Families: A case study of Beijing. Population & Economics 2007, 4, 52-58.
5. Wu, Z.-Q.; Sun, L.; Sun, Y.-H.; Zhang, X.-J.; Tao, F.-b.; Cui, G.-H. Correlation between loneliness and social relationship among empty nest elderly in Anhui rural area, China. Aging and Mental Health 2010, 14, 108-112.
6. China, C.C.o.t.C.P.o. The 14th five-year plan for economic and social development of the people’s republic of China. 2016.
7. Zhang, A.Y.; Yu, L.C.; Yuan, J.; Tong, Z.; Yang, C.; Foreman, S.E. Family and cultural correlates of depression among Chinese elderly. International Journal of Social Psychiatry 1997, 43, 199-212.
8. Petersen, R.C. Mild cognitive impairment: transition from aging to Alzheimer's disease. Alzheimer's disease: advances in etiology, pathogenesis and therapeutics 2001, 141-151.
9. Reitz, C.; Brayne, C.; Mayeux, R. Epidemiology of Alzheimer disease. Nature Reviews Neurology 2011, 7, 137-152.
10. Reisberg, B.; Borenstein, J.; Salob, S.P.; Ferris, S.H. Behavioral symptoms in Alzheimer's disease: phenomenology and treatment. The Journal of clinical psychiatry 1987.
11. Ridley, R.; Baker, H.; Crow, T. Transmissible and non-transmissible neurodegenerative disease: similarities in age of onset and genetics in relation to aetiology. Psychological medicine 1986, 16, 199-207.
12. Friend, C.M.; Zubek, J.P. The effects of age on critical thinking ability. Journal of Gerontology 1958, 13, 407-413.
13. Sternberg, R.J. Older but not wiser? The relationship between age and wisdom. Ageing International 2005, 30, 5-26.
14. Shanshan, L. The elderly start a new consumption trend. Available online: http://finance.people.com.cn/n1/2019/1113/c1004-31451569.html (accessed on 28th, June).
15. Wang, W. New elders lead new consumption trends. Available online: http://finance.people.com.cn/n1/2019/1023/c1004-31414816.html (accessed on 20th, April).
16. Heng, X.; Ren, X.; Zhai, S. Smart pension: the elderly care service innovation with information technology [J]. Scientific Research on Aging 2014, 7, 12-20.

Chapter 4
Perceived value scale of smart homes for the elderly

Chapter 4
Perceived value scale of smart homes for the elderly

4.1 Research purpose

To construct a smart home with all-around wellbeing for the elderly and help them realize independent, safe, and happy life in the old stage, this chapter introduces the PERMA-V wellbeing model to develop a perceived value scale of smart homes for the elderly. It reflects the typical characteristics and core needs of the aging group. The scale comprehensively evaluates the value and potential of smart homes that can help future elders aging in place. It can help related industries fully and accurately grasp the core value demands of older adults and provide a direction and evaluation criteria for the future development of associated enterprises and industries.

4.2 Research method

This chapter follows the standard scale development and validation process [1-3]. The main research methods include literature review, expert interview, user interview, questionnaire survey, and statistical analysis. The research steps are as follows: First, a preliminary pool of measurement items of perceived value was formed through literature research and user interview. Second, an expert interview was conducted to analyze the rationality of all the items, the item expressions were optimized, and relevant contents were refined. Third, a questionnaire was formulated using the optimized measurement items, and a pre-study was conducted to ensure the questions and answers were meaningful. Forth, the final questionnaire of the perceived value of smart homes for the elderly was formed after modification and adjustment according to the analysis result of the pre-study. Fifth, the final questionnaire was used to conduct the main investigation, which includes data collection and analysis. The first-round data was used for exploratory factor analysis, SPSS 25.0 was applied to extract factors and test the validity of relevant factor loading. The second-round data was used for confirmatory factor analysis via AMOS 25.0. According to the data analysis result, the measurement items of the corresponding factors were optimized until all the model fit indexes reach the standard threshold. Last but not least, the constituent factors and measurement items which satisfy all the model fit index threshold was outputted to form the final scale. It is worth mentioning that the perceived value of this study is mainly composed of perceived benefit and perceived cost, so the scale of perceived value includes two parts, the perceived benefit scale, and the perceived cost scale. Among them, perceive benefit has a positive impact on perceived value while perceived cost indicates a negative effect. Therefore, when exploratory factor analysis and confirmatory factor analysis were performed, these two parts were analyzed separately.

4.3 Defining perceived value of smart homes for the elderly

From the perspective of economics, value is a concept about commodity economy. It is the undifferentiated human labor or abstract human labor condensed in commodities that stays abstract, invisible and intangible. For a long time, a large number of researchers have tried to give a standard definition about value, but they failed to reach a consensus in the end. Value shares different definition and presents different meanings in the field of consumer research [4], and its concept shows diversified characteristics [5,6]. In many existing literatures, consumer value is equivalent to consumer perceived value. From the perspective of consumer orientation, there is a clear difference between consumer value and consumer perceived value. The former is a consumer-oriented concept while the later involves consumers' own evaluation and judgment which remains an assessment concept. In the research field of consumer behavior, the concept of perceived value has been widely recognized and used. Under such a cognitive framework, customers are concerned about the benefits they can acquire from the products or services they want to buy and the relevant costs they need to pay, so that they can choose the product or service with the maximum overall value to satisfy their demand[4,7,8].

According to the existing papers, there are mainly two factions of perceived value study. One group is based on Zeithaml's two-dimensional model, which advocates that perceived value is composed of perceived benefit and perceived cost[4]. The other is a multi-dimensional model of perceived value, represented by the five-dimensional model of Sheth which contains functional value, conditional value, social value, emotional value and epistemic value [9]. The results of these researches and explorations have strong reference significance for this study, but their targeted consumers are basically mass consumer groups. When it comes to specific group which shares obvious different physical and psychological characteristics, such as older adults, the existing definition of perceived value and the dimension divisions are too general and do not have pertinent sense. For example, the functional value dimension, is there any difference of the functional needs between aging group and the youth group? What are the functions of smart home that the elderly needs? The general value dimensions could not respond to these questions because they have not taken the characteristics of the elderly into consideration. At the same time, with the advance of society and industry, especially the development of information communication technology and internet of things, the majority of products nowadays are no longer a single physical object, but a system combination composed of hardware, software and humanware. In the upcoming future, all the physical stuffs may be inserted with sensors and form a connected world. Smart homes are the integration of numerous single household products and different service systems. It has huge potential and can serve for all-around user demands. Therefore, for the smart home for the elderly, the composition of its perceived value should be unique and different from the conventional dimensions.

This study combines the characteristics of the elderly and the potential of smart homes in shaping independent, safe, healthy, and happy life for older adults. It follows Zeithaml's academic propositions and basically divides perceived value into perceived benefit and perceived cost. The reason why the author picked up the Zeithaml's theory was because, with regards to value, there is no sense to just focus on the valuable part, it is also important for the users to figure out how much does it cost to gain the certain value. If some products or service systems are of great value for the users, but the cost is beyond their affordability, then the value will not have any positive effect on them and it is unnecessary to have further perception and consideration. Thus, the perceived value in this research has been further divided into perceived benefit and perceived cost. Furthermore, the perceived benefit of smart homes for the elderly has been divided into eight dimensions and perceived cost into three dimensions. The specific definition and composition analysis can be seen in following content.

4.3.1 The definition of perceived benefit of smart homes for the elderly

This study introduces the concept of "wellbeing" to the perceived benefit scale of smart homes for the elderly. Home is supposed to be the heaven of happiness. It is the place where people spend the longest time in their lives. For the aging group, due to the decline in their physical and social functions, after retirement, they are supposed to spend their longest time in home environment. With the improvement of living standards and the development of science and medical technology, human live a longer life and healthier lifestyle nowadays. There are tremendous healthy elders and those who only have several chronic diseases or slight inconvenience in mobility. Therefore, smart homes for the elderly should get rid of the shackles of providing single service or conventional nursing function, and aim at creating an all-around happiness environment for their aging life. Compared to a single product or service, smart home is the integration of numerous products and intelligent service systems. This combination determines that smart homes have the functions beyond the conventional single product or service, and provide the possibility and huge potential of shaping all-around wellbeing for the elderly in home life. PERMA-V model, proposed by Martin Seligman, the "father of positive psychology", which is considered to be the most comprehensive framework of “the good life”. Thus, the author takes the PERMA-V wellbeing model of positive psychology as theory basis and further divides the dimensions of perceived benefit of smart homes for the elderly into PERMA-IHS, they are "Positive Emotion", "Engagement", "Relationship", "Meaning", "Achievement", "Independence", "Healthcare", "Safety", in total eight dimensions. Among them, PERMA is retained from the original model, “V” from PERMA-V model which means “Vitality” has been further divided into IHS, namely "Independence", "Healthcare", "Safety". “Vitality” is integral to people’s wellbeing, which provides the physical essence and foundation for the realization of other five factors PERMA. When it comes to older adults, the importance of the physical foundation has been further emphasized and given great concerns due to their specific physical situation, they will suffer from degeneration of sensory system, skeletal and muscle system, cardiopulmonary system as well as high incidence of chronic disease with the increase of age. These situations make them quite different from youth and ordinary people in physical aspects. In fact, to some extent, the significance of the existence of smart homes for the elderly is to make up for their weaken physiological functions and solve the problems they may face with. According to the literature review of smart homes for the elderly, it is found that, when the majority of authors mentioned the benefits of smart home, there are three words, namely independence, healthcare, safety, their occurrence frequency is extremely high. It is not difficult to understand that with the decline of the physical and social functions of the elderly, their ability to live independently will continue to be weaken and challenged. The application of smart technology can bring convenience and efficiency to them, and make up for the weakened physiological functions. Simultaneously, as the age increases, various health problems will follow one after another, so healthcare plays a crucial role in the elderly’s daily life. Moreover, as a vulnerable group, the safety of the elderly will also be subject to various threats and challenges. Compared with young people, their cognition, perception and judgement abilities become weaker, and there could be various incidence and dangers in personal safety, environmental safety, property safety, etc. Thus, the author took “Independence”, ”Healthcare”, ”Safety” as the physical foundation of the benefit of smart homes for future elderly instead of the single word “vitality” in PERMA-V model, which could reflect the needs and characteristics of the elderly more directly and profoundly. The following is the detailed definition of the relevant sub-dimensions of perceived benefit in this study:

- **Independence:** The benefit of "independence" means that smart homes can bring efficiency and convenience to healthy or mildly disabled elders through smart products and services to help them get rid of dependence on others, achieve self-reliance, self-management, self-care and live with dignity. It mainly reflected in the home smart technology to meet the basic needs of the elderly, including clothing, eating, housing, moving, and using, such as the automatic control of home appliances, online shopping, take-out foods, taxi calls, picking up express delivery, washing clothes, housekeeping services, etc.
- **Healthcare:** The benefit of "healthcare" means that smart homes can help the elderly realize the management, prevention, treatment and rehabilitation of healthy problems and diseases in home environment to live a healthy lifestyle through smart products and services. It mainly includes the detection and management of physical health through smart medical equipment, online medical consultation, telemedicine, embedded fitness equipment, rehabilitation training equipment, etc.
- **Safety:** The benefit of "safety" means that smart homes can ensure the physical safety, social safety, environmental safety, and property safety of the elderly through smart products and services. Among them, the physical safety of the elderly mainly reflects by the emergency detection and responses, such as sudden heart attacks, falls, etc. Social safety means that the elderly can always get support and help from relevant social forces when they need it. Property safety is mainly reflected from the anti-theft monitoring system through smart doors, windows, cameras, etc. Environmental safety is mainly reflected by the monitor of air, water, electricity, fire, etc. in the home environment to prevent accidents such as gas leak and fire disaster.
- **Positive emotion:** The benefit of "positive emotion" means that smart homes can help the elderly maintain good emotions status through smart products and services, making them feel comfortable, relaxed, enjoyable, excited, loved, and get rid of negative emotions such as loneliness or depression. It mainly includes two aspects. On the one hand, smart home could provide smart home theater, smart game equipment, smart party system, etc. to enable the elderly to engage in different entertainment and social activities, such as listening to music and radio, watching TV series, watching movies, playing chess and card games, family gatherings, etc. On the other hand, smart home could integrate lighting systems, temperature and humidity Control systems, door and window systems, etc. to regulate the lighting, temperature, and humidity control to create a comfortable living environment for the elderly.
- **Engagement:** The benefit of "engagement" means that smart homes can help the elderly to engage in activities related to their hobbies and competence in home life through smart products and services. The elderly could enter a state of "heart flow", forgetting time and space, and feel unparalleled happiness from the things they are engaged in. The shaping of engagement mainly includes intelligent information system, intelligent education system, intelligent interest assistance system, etc., to help the elderly master, learn and engage in knowledge and activities that they are interested in.
- **Relationship:** The benefit of "relationship" means that smart homes can help the elderly develop and strengthen their interpersonal bond with the outside world and promote their

social interaction through smart products and services. The main objects include their relatives, friends, families, children, couple, pets, related organizations and institutions. Moreover, it can also include the enhancement of the belief or religious connection of the elderly, the development of social companion robots based on artificial intelligence technology, and even the connection with nature through surroundings or the use of virtual reality to enhance their experience about the virtual nature.

- **Meaning:** The benefit of "meaning" means that smart homes can help the elderly to find the purpose and direction of life, provide opportunity to allow them continue making social contribution or reemployment to realize their value of existence after retirement. For example, using the Internet technology and platform to help them achieve re-employment, do freelance work, create start-ups, join online volunteer community to contribute to society, provide remote peers support, help children take care of grandchildren, master knowledge and skills through online study to complete unfulfilled wishes, etc.
- **Achievement:** The benefit of "achievement" means that smart homes can help the elderly to accomplish what they can do and gain a sense of accomplishment. For smart homes, it mainly includes the sense of reality achievement and virtual achievement. The sense of reality achievement includes helping the elderly to be appreciated, concerned, and gain the recognition and respect from others or acquire social status through their hobbies, talents, works, etc. The sense of virtual achievement is mainly reflected in the smart home helping the elderly to get likes, comments, fans, and attention on the Internet platform or social media, even in virtual game system to obtain high rank of game character or virtual gaming wealth, etc.

4.3.2 The definition of perceived cost of smart homes for the elderly

Before giving the definition of perceived cost, the author wants to clarify that this research targets on refurbished house for smart home. The newly designed smart home is not taken into consideration. The reasons are as follows: first, as the research background mentioned, 90% of Chinese older adults choose to live at home after retirement, they share nostalgia and deep emotion for the place they used to live in, so that the smart home in this research is focusing on how can smart home help the elderly aging in place and spend their older life in their familiar environment. If for newly designed smart home, it will lose this kind of meaning. Second, in China, the elderly always save money for their children or grandchildren to buy new houses for marriage or study, they seldom invest in new house specifically for themselves, like smart home, to spend their retirement time. This kind of consumption culture makes the research of newly designed smart home shares low necessity and implies that refurbished house should be given the emphasis. Last but not least, some real estate company in China try to expand their business landscape via targeting on older adults, but they suffer from huge economic loss. There should be some Chinese elderly who are willing to paying for new smart house, and in the future, the consumption preference of the most Chinese elderly may be somehow changed, but the percentage and possibility stays really low.

Based on the analysis above, the perceived cost of smart homes for the elderly should be the elderly's perception of the cost they need to pay in order to use smart home products and services. These necessary costs mainly include "monetary cost", "study cost", and "space cost". It is worth mentioning that, for the elderly with different economic abilities, education backgrounds, and cognitive levels, their perception of corresponding costs should be different.

The following is the definition of related cost dimensions in this study.

- **Monetary cost:** The "Monetary cost" refers to the money that the elderly need to pay during the purchase, transportation, installation, usage, maintenance process of relevant smart home products and services.
- **Study cost:** The "Study cost" refers to the time, energy, money, intelligence investment of the elderly to learn the usage and operation of related products, equipment, and service systems.
- **Space cost:** The "Space cost" refers to the investment that the elderly need to pay for changing the original arrangement of the living environment, removing and discarding of old products and equipment, redecoration and rearrangement of network layout in order to use smart home products and services.

4.4 Preliminary works

4.4.1 Items generation

In order to give a convincing and systematic review about the value and benefit of smart home for elderly. The author has searched the global mainstream literature databases, including Web of science, Scopus, IEEE Xplore, with keywords "smart home", "older adult", "perception" and their synonyms. 2110 articles were collected in total. The specific search results are shown in Table 1.

Table 1. Database, Search Terms and Hits

Database	Search Terms	Hits
Web of Science(1990-2020)	("smart home" OR "smart-home" OR "smart house" OR "remote house" OR "intelligent home" OR "intelligent house" OR "home automation system" OR "house automation system" OR "automated home" OR "automated house") AND ("older adult" OR "Elderly" OR "senior" OR "elder" OR "older person" OR "older people" OR "aged" OR "aging" OR "middle-aged") AND ("perception" OR "Adoption" OR "acceptance" OR "acceptability" OR "need" OR "demand" OR "requirement" OR "attitude" OR "behavior" OR "awareness" OR "willingness" OR "barrier" OR "difficulty" OR "assessment" OR "evaluation" OR "measurement" OR "measure")	473
Scopus(1990-2020)		1354
IEEE Xplore(1990-2020)		283

Among the 2110 articles, 852 duplicate articles were deleted, 59 unnamed articles were deleted, and the remaining 1199 articles were screened by title, abstract and full text. In the end, 64 articles were selected as the materials of literature review. From the existing articles, we refined and summarized keywords for the perceived benefit and perceived cost of smart home for the elderly. After deleting and merging synonyms as well as adding some new keywords, the author had gained Table 2. The table shows the key components of perceived benefit and perceived cost of smart homes for the elderly and synonyms are placed in brackets for similar components. Based on it, the initial measurement items of each dimension were generated. Then, a small range of user interview was conducted. The author randomly selected 15 future elderly people aged 45-60, and asked them about their understanding of the generated measurement items, as well as other important value demands that were not reflected or fully reflected in the existing variables and measurement items. According to their understanding and reflection, the language expression and content of each items have been modified and optimized. Some new items and content have been added. Through the literature review and user interview, the item pool of perceived value of smart homes for future elderly has been formed.

Table 2. Measurement item categories, keywords, and references

Perceived Value	Statements	Sources
Perceived Benefit		
Independence (IND)	Self-reliance (Daily life assistance, Life assistance, Support autonomous living), Self-management (Energy management, Daily activity tracking, Remote control, Home automation), Self-care (Self-support, Medicines and tasks reminders), Efficiency (Effectiveness, Productivity, Convenience), Escape from indignity (Dignity, Life autonomy)	[10] [11] [12] [13] [14] [15] [16] [17] [18] [19] [20] [21] [22] [23] [24] [25] [26] [27] [28] [29] [30] [31] [32] [33] [34] [35] [36] [37] [38] [39] [40] [41] [42] [43] [44] [45] [46]
Healthcare (HEA)	Health management (Health detection, Health and nutrition, Health monitoring, Chronic diseases management, Physiological parameter monitoring), Disease prevention (Exercise, Training cognitive functions, Cognitive stimulation), Teleconsultation(Consultancy), Telemedicine(Prediction of mild cognitive impairment, Incipient disease symptoms highlight, Cognitive support, Therapy),Telecare(Healthy information exchange, Sensory aids), Rehabilitation(Physical rehabilitation and fitness), Medication administration(Medical administration communication)	[12] [13] [47] [14] [15] [16] [18] [19,20] [22] [48] [25] [26] [27] [28] [29] [49] [30] [31] [32] [35] [36] [37] [38] [39] [40] [41] [42] [43] [44] [46]
Safety (SAF)	Life safety (Abnormal behavior detection, Fall detection, Fall prevention), Social safety, Environment monitoring(House security, Security monitoring), Property safety, Emergency response(Emergency assistance, Emergency detection)	[10] [13] [14] [15] [18] [20] [50] [22] [23] [26] [27] [28] [29] [30] [31] [32] [35] [37] [38] [39] [40] [41] [42] [43] [45]
Positive emotion (PE)	Comfort, Relax (Relaxation, Relief of pressure, Workload relief, Leisure), Calm(Unobtrusive, Peace of mind), Enjoyable(Fun, Entertainment, Recreation and entertainment, Virtual reality), Delighted (Pleasure), Excited, Loved(Emotional interactive)	[47] [14] [15] [16] [17] [21] [22] [51] [25] [26] [29] [30] [31] [32] [36] [36] [37] [38] [42]
Engagement (ENG)	Competence tasks (Tasks and appointments), Interest development, Knowledge and skills, Absorption and concentration(Activity engagement), Lose track of time and space	[11] [31] [32] [38]
Relationship (REL)	Family(Couple, Children), Friends, Social interaction(Social life, Social communication), Companionship (Robots, Pet), Belief (Religion),Nature(Biophilic experience), Organization, Institution	[11] [12] [47] [15] [19] [52] [49] [53] [30] [31] [32] [35] [37] [40] [42] [43] [44] [46]

Meaning (MEA)	Life purpose, Family responsibility (Grandchildren babysitting), Social contribution, Unfulfillment (Uncompleted wishes fulfillment), Reemployment, Peers support,	[49] [31] [32] [40]
Achievement (ACH)	Progress in life, Reach goals, Good, Confident, Proud, Sense of accomplishment (Reality accomplishment, Virtual accomplishment)	[31] [32]
Perceived Cost		
(Monetary) Cost	Product price, Service price, Accessory price, Installation fee, Maintenance fee (Repair), Transportation fee	[53] [46]
Study Cost	Time investment, Money investment, Energy investment, Interpersonal help, Lack of knowledge and experience (Legislation and regulations, Standardization, Operation)	[17] [46]
Space Cost	House arrangement, House decoration, Old equipment and furniture removement, Network layout	

4.4.2 Refinement and item reduction

The item pool formed for perceived value through literature review and user interview contained 76 items. They were divided into two parts, the perceived benefit items and the perceived cost items. For the perceived benefit, there were 7 items for Independence, 7 for Healthcare, 6 for Safety, 10 for Positive emotion, 5 for Engagement, 10 for Relationship, 6 for Meaning, 6 for Achievement, 61 in total. With regard to perceived cost, there were 5 items for Monetary cost, 6 for Study cost, and 4 for Space cost, 15 in total. After acquiring the item pool, expert interview was conducted to evaluate the validity of each dimensions and each measurement items of perceived value. A total of 10 experts participated in this research, including 4 PhD candidates and 3 Professors whose research field is aging society, 3 workers in the smart home industry. We use the mode of remote interviews through Tencent Conference and ZOOM to ask experts to present their opinions on the rationality, suitability, validity of each perceived value dimensions and relevant measurement items. At the same time, the expression and meaning delivery of each items have also been emphasized. Due to their suggestions and advice, the author made modification of all the items which consider keeping, adding, deleting, merging, revising or dimensional adjustments. The final items for perceived benefit are 6 items for Independence, 7 for Healthcare, 5 for Safety, 7 for Positive Emotion, 5 for Engagement, 7 for Relationship, 5 for Meaning, 6 for Achievement, 48 in total. Regarding perceived cost, there were 5 for Monetary cost, 6 for Study cost, 4 for Space cost, 15 in total. The detailed measurement items are shown in Table 3 and Table 4.

Table 3. The items of perceived benefit scale

Perceived Benefit	**Items**	
Independence (IND)	IND1	Smart homes can help me realize self-reliance.
	IND2	Smart homes can help me realize self-care.
	IND3	Smart homes can help me realize self-management.
	IND4	Smart homes can help me improve daily life efficiency.
	IND5	Smart homes can make my life more convenient.
	IND6	Smart homes can provide products and services to help with my weaken ability.
Healthcare (HEA)	HEA1	Smart homes can detect my health data and give timely feedback to me.
	HEA2	Smart homes can let me exercise at home and realize disease prevention.
	HEA3	Smart homes can provide teleconsultation for me.
	HEA4	Smart homes can provide telemedicine services for me.
	HEA5	Smart homes can provide telecare for me when I need it.
	HEA6	Smart homes can help me with the rehabilitation if I got serious disease or finished a surgery.
	HEA7	Smart homes can help me keep contact with my medical administration.
Safety (SAF)	SAF1	Smart homes can ensure my life's safety.
	SAF2	Smart homes can ensure my social safety.
	SAF3	Smart homes can ensure my environmental safety.
	SAF4	Smart homes can ensure my property safety.
	SAF5	Smart homes can provide the emergency responses if I got any accident at home.
Positive emotion (PE)	PE1	Smart homes can enable me to feel comfortable.
	PE2	Smart homes can enable me to feel relaxed.
	PE3	Smart homes can enable me to feel calm.
	PE4	Smart homes can enable me to feel joyful.
	PE5	Smart homes can enable me to feel delighted.
	PE6	Smart homes can enable me to feel excited.

	PE7	Smart homes can enable me to feel I am loved.
Engagement (ENG)	ENG1	Smart homes can provide me with competent tasks.
	ENG2	Smart homes can provide me with the support of my interest development.
	ENG3	Smart homes can enable me to learn knowledge and skills which I want to learn.
	ENG4	Smart homes can enable me to get the state of absorption and concentration.
	ENG5	Smart homes can enable me lose track of time and space while doing something I enjoy.
Relationship (REL)	REL1	Smart homes can provide the functions and services to increase the family interaction.
	REL2	Smart homes can strengthen my social life and cultivate connections to others.
	REL3	Smart homes can provide me with companionship.
	REL4	Smart homes can provide the functions and services to help me strengthen the connection with my belief.
	REL5	Smart homes can provide the functions and services to help me feed my pets.
	REL6	Smart homes can provide the functions and services to strengthen my biophilic experience and the connection with nature.
	REL7	Smart homes can provide the functions and services to strengthen my friendship.
Meaning (MEA)	MEA1	Smart homes can make me feel I have a sense of direction and purpose in my life.
	MEA2	Smart homes can help me to do family responsibilities.
	MEA3	Smart homes can enable me to make social contribution via technology and Internet.
	MEA4	Smart homes can help me do some things which I could not do when I am young via smart technology.
	MEA5	Smart homes can enable me to do re-employment via technology and the Internet.
Achievement (ACH)	ACH1	Smart homes can help me make progress in life.
	ACH2	Smart homes can help me achieving my goals.
	ACH3	Smart homes can help me feel good about myself.
	ACH4	Smart homes can help me feel confident about myself.
	ACH5	Smart homes can help me feel proud of myself.
	ACH6	Smart homes can help me have a sense of accomplishment in life.

Table 4. The items of perceived cost

Perceived Cost		**Items**
Monetary Cost (MON)	MON1	If I want to use smart homes when I am old, I need to buy related products and equipment.
	MON2	If I want to use smart homes when I am old, I need to pay for related services.
	MON3	If I want to use smart homes when I am old, I need to pay for installation fee.
	MON4	If I want to use smart homes when I am old, I need to pay for maintenance fee.
	MON5	If I want to use smart homes when I am old, I need to pay for Transportation fee.
Study Cost (STU)	STU1	If I want to use smart homes when I am old, I need to spend time learning how to use it.
	STU2	If I want to use smart homes when I am old, I need to spend money learning how to use it.
	STU3	If I want to use smart homes when I am old, I need to spend energy learning how to use it.
	STU4	If I want to use smart homes when I am old, I need to seek for others help to teach me how to use it.
	STU5	If I want to use smart homes when I am old, I need to learn related legislation and regulations.
	STU6	If I want to use smart homes when I am old, I need to learn related industry standardization.
Space Cost (SPA)	SPA1	If I want to use smart homes when I am old, I need to change the arrangement of my house.
	SPA2	If I want to use smart homes when I am old, I need to change the decoration of my house.
	SPA3	If I want to use smart homes when I am old, I need to remove the old equipment and furniture in my house.
	SPA4	If I want to use smart homes when I am old, I need to rearrange the network layout of my house.

4.4.3 Questionnaire design

After clarifying the dimensions of perceived value and generating relevant measurement items, the author compiled a questionnaire including all the generated items. The questionnaire mainly consists of two parts. The first part is the demographic information of the survey respondents, including age, gender, occupation, monthly income, marital status. The second part is the perceived value scale of smart homes for future elderly, which mainly includes the perceived benefit scale and the perceived cost scale, see Appendix A. All the questions have been given a specific condition "When I am old" and all the items have been measured through 5-point Likert scale, during which "1" is "strongly disagree", "2" is "disagree", "3" is "general", "4" is "agree", and "5" "is "strongly agree".

4.4.4 Pre-study

Before starting large scale investigation, a pre-study was conducted to check the consistency, clarity and reliability of the questionnaire. The scale was formatted in a 5-point Likert scale and 57 middle-aged people aged from 45-60 were recruited in the pilot study. Depending on the data result, some confusing questions and long statement were accordingly modified. Accordingly, SPSS 25.0 was used to evaluate the consistency and reliability of the questionnaire. The Cronbach's α of the pilot study was 0.875, which was above the threshold of 0.7 and indicated that the questionnaire had satisfactory reliability.

4.5 Scale development and factor analysis

This section attempts to identify the measurement items of the perceived value scale and examine the related reliability and validity of different constructs and measurements. Specifically, all 48 items for perceived benefit and 15 items for perceived cost were gathered to form a questionnaire and all the items are measured based on a 5-point Likert scale. Participants would respond to each item scale from 1=strongly disagree to 5=strongly agree. SPSS25.0 and AMOS 25.0 for Windows were used to conduct statistical analysis, the exploratory factor analysis (EFA) and confirmatory factor analysis (CFA) were used to test the distinctive constructs and model fit indices of the theoretical structure.

4.5.1 Exploratory factor analysis

Exploratory factor analysis (EFA) was conduct to reduce the dimensionality and explore the appropriate structure of the perceived value scale, which is mainly consisted of two part, the perceived benefit scale and the perceived cost scale.

4.5.1.1 Respondents

The author conducted online questionnaire survey through Wenjuanxing, a famous Chinese questionnaire survey platform to gain the data for exploratory factor analysis. The age of participants has been limited in 45-60, 339 responses have been collected. To be more specific, 191(56.3%) participants were male and 148(43.7%) were female. With regard to the ages, 102(30.0%) were between the age of 45 and 50, 201(59.3%) were between the age of 51 and 55, 36(10.6%) were between the age of 56 and 60. The education level, marital status, income and occupation information also have been clarified, which can be seen in Table 5.

Table 5. Demographic information for exploratory factor analysis

Attribute	**Value**	**Freq.**	%	**Attribute**	**Value**	**Freq.**	%
Gender	Male	191	56.3		<1000	34	10.0
	Female	148	43.7	Monthly	1000-3000	77	22.7
Age	45-50	102	30.0	Income	3000-5000	87	25.7
	51-55	201	59.3	(RMB)	5000-7000	98	28.9
	56-60	36	10.6		7000-10000	16	4.7
Education	<High school	110	34.4		10000+	27	8.0
	High school	70	20.6	Occupation	Teacher	20	5.9
	Associate	67	19.8		Civil Servant	19	5.6
	Bachelor	48	14.2		IT company staff	19	5.6
	Master	30	8.8		Non-IT company staff	97	28.6
	Doctor	14	4.1		Private entrepreneur	21	6.2
Marital	Single	40	11.8		Freelancer	14	4.1
status	Married	256	75.5		Worker	94	27.8
	Divorced	35	10.3		Farmer	18	5.3
	Widowed	8	2.4		Others	37	10.9

4.5.1.2 Exploratory factor analysis of perceived benefit

A principal axis factoring analysis with varimax orthogonal rotation was conducted. For the exploratory factor analysis of perceived benefit scale, the results showed the Kaiser-Meyer-Olkin(KMO) measure of sampling was 0.929 and Bartlett's test(Chi-square) value was 10482.943 (p=0.000), suggesting that it is suitable for factor analysis [54]. Each construct was examined and determined in terms of eigenvalues and the scree plot. In terms of item selection for the eight factors, all the items were appealed to the condition that singly loading onto one factor with coefficients greater than 0.50 [55]. Factor loadings with varimax rotation were provided in Table 6.

Table 6. Varimax rotation method for the perceived benefit scale in eight factors

Item	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7	Factor 8
HEA7	.799	.142	.120	.236	.094	.064	.071	.237
HEA1	.765	.156	.159	.270	.120	.023	.143	.215
HEA4	.762	.133	.167	.166	.171	-.018	.146	.109
HEA2	.743	.166	.223	.225	.131	.050	.132	.151
HEA3	.712	.166	.167	.184	.118	.022	.110	.101
HEA5	.696	.154	.140	.246	.090	.030	.168	.128
HEA6	.650	.063	.153	.288	.076	.099	.113	.080
PE1	.092	.789	.121	.101	.147	-.061	.012	.115
PE3	.111	.782	.116	.062	.066	.079	.083	.007
PE7	.116	.770	.171	.132	.078	.028	.033	-.003
PE6	.091	.756	.219	.069	.132	.096	.140	.151
PE4	.157	.753	.141	.126	.143	.036	.169	.085
PE5	.199	.740	.124	.181	.099	.037	.073	.076
PE2	.099	.733	.223	.194	.163	-.025	.012	.019
IND4	.140	.160	.764	.210	.088	.008	.093	.056
IND3	.176	.176	.760	.217	.153	-.095	.036	.141
IND1	.239	.199	.760	.165	.168	.001	.071	.094
IND2	.209	.185	.715	.176	.063	.002	.079	.088
IND6	.094	.261	.701	.196	.125	.001	.073	.042
IND5	.201	.212	.692	.273	.094	.077	.116	.109
REL2	.299	.175	.259	.689	.107	.024	.082	.130
REL4	.262	.184	.160	.681	.126	.070	.019	.259
REL7	.241	.137	.221	.667	.087	.056	.105	.107
REL1	.351	.125	.303	.620	.081	.036	.187	.104
REL3	.362	.156	.260	.612	.033	.071	.103	.209
REL5	.343	.199	.246	.605	.035	.056	.145	.057
REL6	.303	.229	.295	.605	.086	-.021	.096	.108
MEA5	.055	.158	.138	.086	.829	.017	.197	.130
MEA1	.176	.108	.087	.040	.789	.046	.178	.191
MEA4	.134	.149	.147	.108	.769	.046	.179	.164
MEA2	.127	.208	.122	.117	.762	-.018	.162	.125
MEA3	.147	.163	.117	.043	.716	.088	.099	.221
ACH2	-.021	-.045	-.016	.002	.018	.780	.022	.066
ACH6	.071	.052	-.011	.078	.023	.778	.023	-.103
ACH1	.025	.024	-.015	.028	.003	.751	-.046	.055
ACH3	.064	.065	.089	.020	.013	.743	-.066	.016
ACH4	.061	.057	-.017	.000	.043	.740	-.003	.006
ACH5	-.023	-.013	-.024	.032	.031	.710	-.024	-.043
SAF4	.146	.087	.111	.093	.128	-.062	.778	.104
SAF1	.184	.037	.163	-.013	.193	-.045	.742	.200
SAF3	.056	.115	.056	.125	.237	.033	.701	.146
SAF5	.239	.060	.042	.020	.130	-.025	.679	.186
SAF2	.071	.134	.035	.231	.088	-.038	.678	.178

ENG5	.190	.060	.053	.190	.144	-.034	.201	.723
ENG3	.172	.041	.182	.020	.175	.038	.148	.696
ENG2	.134	.110	.142	.164	.139	-.087	.119	.693
ENG1	.150	.088	.032	.186	.184	.037	.345	.670
ENG4	.218	.105	.047	.151	.273	.057	.186	.656

Notes: Rotation method: Varimax. Extraction method: Principal axis factoring. Rotation converged in seven iterations with loading values of more than 0.5.

4.5.1.3 Exploratory factor analysis of perceived cost

For the exploratory factor analysis of perceived cost scale, the results showed the Kaiser-Meyer-Olkin(KMO) measure of sampling was 0.937 and Bartlett's test(Chi-square) value was 3212.436 (p=0.000), suggesting that it is suitable for factor analysis [54]**.** Each construct was examined and determined in terms of eigenvalues and the scree plot. In terms of item selection for the eight factors, all the items were appealed to the condition that singly loading onto one factor with coefficients greater than 0.50 [55]**.** Factor loadings with varimax rotation were provided in Table 7.

Table 7. Varimax rotation method for the perceived cost scale in three factors

Items	Factor 1	Factor 2	Factor 3
STU4	.807	.247	.255
STU1	.787	.249	.203
STU2	.780	.287	.074
STU5	.774	.198	.190
STU3	.764	.184	.150
STU6	.727	.303	.144
MON1	.226	.786	.167
MON3	.264	.781	.238
MON2	.268	.781	.218
MON4	.259	.780	.210
MON5	.324	.752	.221
SPA3	.193	.173	.846
SPA1	.143	.184	.826
SPA4	.170	.207	.800
SPA2	.216	.275	.766

4.5.2 Confirmatory factor analysis

Based on the result of the exploratory factor analysis, confirmatory factor analysis (CFA) was used to evaluate the perceived value scale, which including 48 items for perceived benefit scale and 15 items for perceived cost scale.

4.5.2.1 Respondents

The similar data collection method with exploratory factor analysis was applied. Online questionnaire survey through Wenjuanxing was conducted with the age limitation between 45 to 60 for the participants. 561 responses have been collected. To be more specific, 306(54.5%) participants were male and 255(45.5%) were female. With regard to the ages, 169(30.1%) were between the age of 45 and 50, 347(61.9%) were between the age of 51 and 55, 45(8.0%) were between the age of 56 and 60. The education level, marital status, income and occupation information also have been presented in Table 8.

Table 8. Demographic information for confirmatory factor analysis

Attribute	Value	Freq.	%	Attribute	Value	Freq.	%
Gender	Male	306	54.5		<1000	46	8.2
	Female	255	45.5	Monthly	1000-3000	143	25.5
Age	45-50	169	30.1	Income	3000-5000	133	23.7
	51-55	347	61.9	(RMB)	5000-7000	158	28.2
	56-60	45	8.0		7000-10000	41	7.3
Education	<High school	199	35.4		10000+	40	7.1
	High school	108	19.3	Occupation	Teacher	29	5.2
	Associate	105	18.7		Civil Servant	31	5.5
	Bachelor	85	15.2		IT company staff	34	6.1
	Master	44	7.8		Non-IT company staff	155	27.6
	Doctor	20	3.6		Private entrepreneur	35	6.2
Marital	Single	75	13.4		Freelancer	22	3.9
status	Married	426	75.9		Worker	172	30.7
	Divorced	51	9.1		Farmer	29	5.2
	Widowed	9	1.6		Others	54	9.7

4.5.2.2 Confirmatory factor analysis of perceived benefit

The results showed that the original model did not provide an adequate model fit (X^2=1852.383; p=0.000; SRMR=0.037; RMSEA=0.037; CFI=0.947; NFI=0.885; IFI=0.947; TLI=0.943; GFI=0.882). Following the suggestions from Woosnam and Norman, reasonable modifications were introduced based on the correlated residuals and cross-loadings, producing a good model fit[56]. Regarding this, the first modified model contained 43 items, producing a better model fit for the data (X^2=1529.580; p=0.000; SRMR=0.037; RMSEA=0.039; CFI=0.949; NFI=0.895; IFI=0.949; TLI=0.945; GFI=0.890). However, the vital index NFI and GFI still can not reach the threshold so that the second modification was conducted. The second modified model contained 38 items based on the first revision, which indicates that all the model fit indices thresholds have been reached (X^2=1190.188; p=0.000; SRMR=0.037; RMSEA=0.039;

CFI=0.953; NFI=0.905; IFI=0.954; TLI=0.948; GFI=0.903). Table 9 presents the model fit indices for the original and revised models. Figure 4.1 shows the path diagram of the second model modification of the perceived benefit scale of smart home for future elderly.

Table 9. Model fit for perceived benefit scale.

Models	X^2	d.f.	X^2/d.f.	SRMR	RMSEA	CFI	NFI	IFI	TLI	GFI
Item 48	1852.383	1052	1.761	0.037	0.037	0.947	0.885	0.947	0.943	0.882
Item 43	1529.580	832	1.838	0.037	0.039	0.949	0.895	0.949	0.945	0.890
Item 38	1190.188	637	1.868	0.037	0.039	0.953	0.905	0.954	0.948	0.903
Threshold			1-5	0.08	0.08	0.90	0.90	0.90	0.90	0.90

Note: SRMR represents standardized root mean square residual; RMSEA represents root mean square error of approximation; CFI represents the comparative fit index; NFI represents normal fit index; IFI represents the incremental fit index; TLI represents Tucker-Lewis Index; GFI represents the goodness of fit

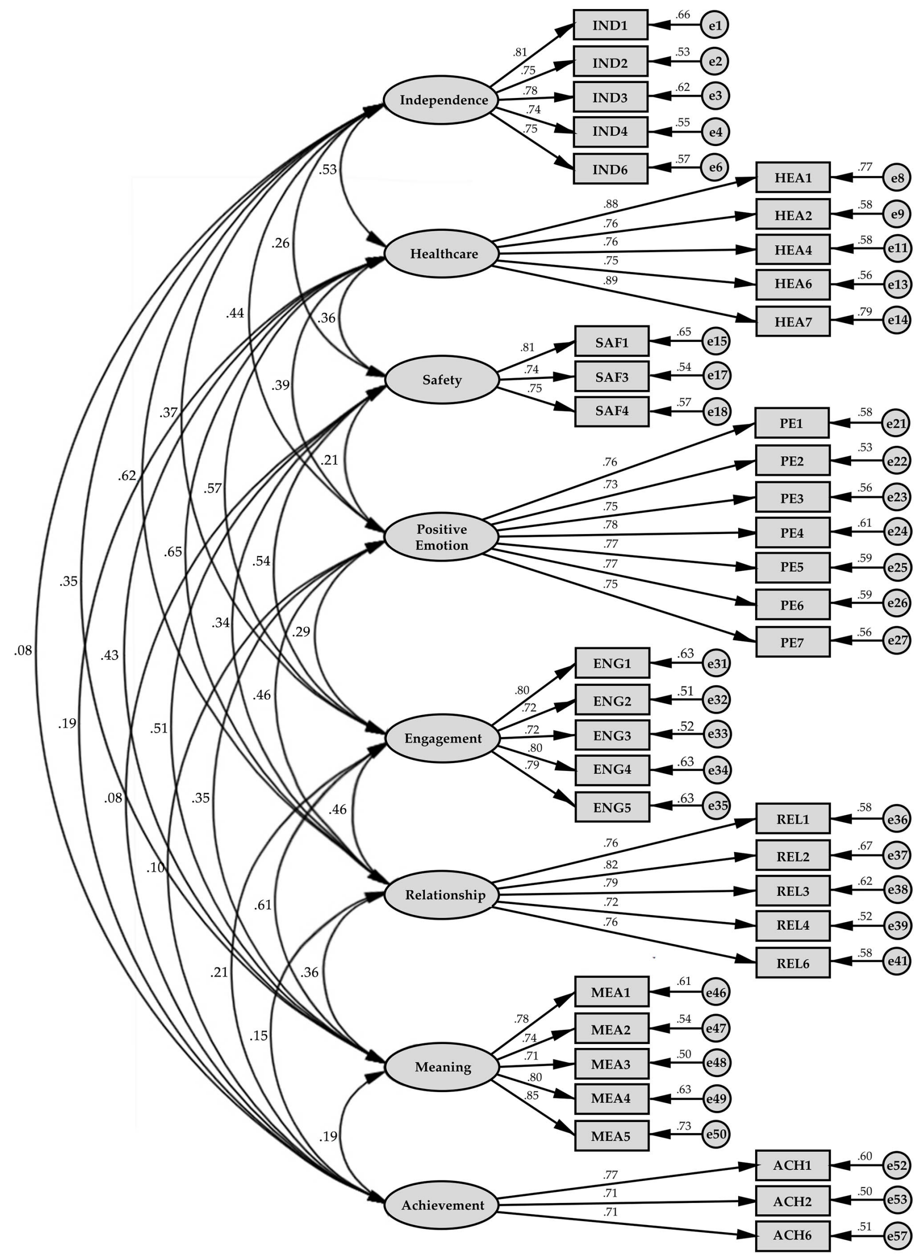

Figure 4.1. The path diagram of the perceived benefit scale

4.5.2.3 Confirmatory factor analysis of perceived cost

After the analysis of perceived benefit, confirmatory factor analysis of perceived cost was applied. The results showed that the original model provided an adequate model fit and all the model fit indices thresholds have been reached. Table 10 presents the model fit indices for the original models (X^2=180.106; p=0.000; SRMR=0.034; RMSEA=0.044; CFI=0.982; NFI=0.965; IFI=0.982; TLI=0.978; GFI=0.960). Figure 4.2 shows the path diagram of the second model modification of the perceived benefit scale of smart home for future elderly.

Table 10. Model fit for perceived cost scale.

Models	X^2	d.f.	X^2/d.f.	SRMR	RMSEA	CFI	NFI	IFI	TLI	GFI
Item 15	180.106	87	2.070	0.034	0.044	0.982	0.965	0.982	0.978	0.960
Threshold			1-5	0.08	0.08	0.90	0.90	0.90	0.90	0.90

Note: SRMR represents standardized root mean square residual; RMSEA represents root mean square error of approximation; CFI represents the comparative fit index; NFI represents normal fit index; IFI represents the incremental fit index; TLI represents Tucker-Lewis Index; GFI represents the goodness of fit.

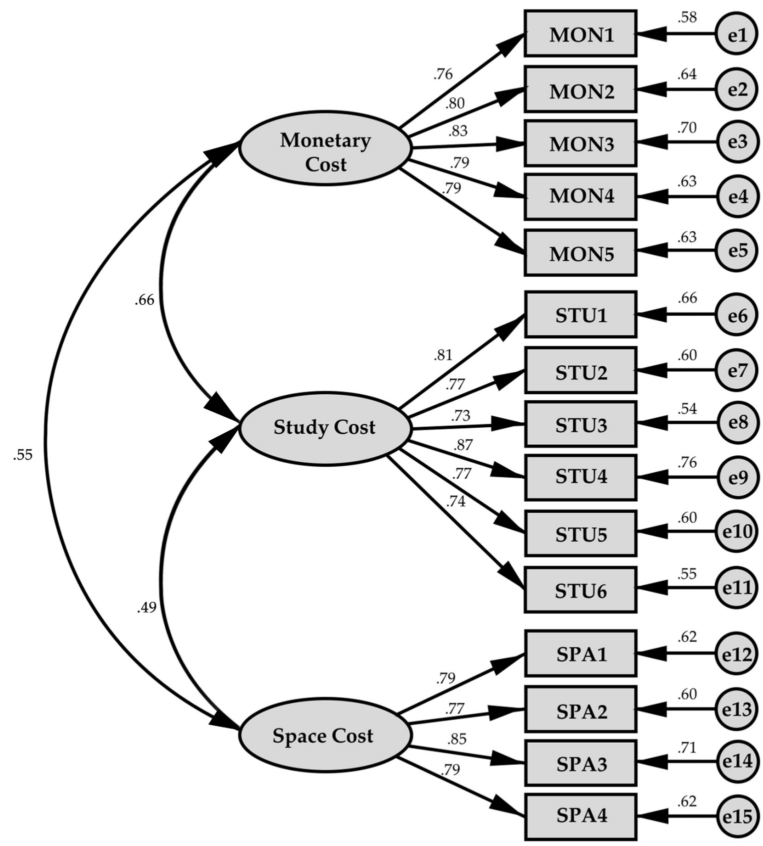

Figure 4.2. The path diagram of the perceived cost scale

4.5.3 Convergent and discriminant validity

4.5.3.1 Convergent and discriminant validity of perceived benefit

Confirmatory factory analysis was conducted to determine the convergent and discriminant validity of the perceived benefit scale. For convergent validity, the standardized factor loadings should be above the threshold 0.5 or above, C.R. (t-value) should be above the threshold 2 or above, and the averaged variances expected (AVE) value should also be above the threshold 0.5 or above [57]. Table 11 shows that the C.R. (t-value), standardized factor loadings, and AVE all achieved adequate values.

Table 11. Convergent and discriminant validity of the perceived benefit scale.

Construct	Cronbach's Alpha	Variable	Mean	Standard Deviation	Standardized Factor Loading	C.R. (t-Value)	SMC	AVE	Composite Reliability
		IND1	4.06	1.079	0.813	-	0.662	0.584	0.875
		IND2	3.80	0.989	0.727	17.903	0.528		
Independence	0.875	IND3	3.96	1.040	0.784	19.972	0.615		
		IND4	3.76	1.026	0.739	18.607	0.547		
		IND6	3.87	0.971	0.755	19.222	0.569		
		HEA1	3.88	1.060	0.880	-	0.774	0.657	0.905
		HEA2	3.69	1.135	0.762	22.012	0.581		
Healthcare	0.903	HEA4	3.66	1.044	0.762	21.732	0.580		
		HEA6	3.68	1.101	0.749	21.487	0.561		
		HEA7	3.73	1.064	0.887	29.189	0.786		
		SAF1	3.47	1.126	0.807	-	0.651	0.587	0.810
Safety	0.809	SAF3	3.45	1.088	0.738	16.108	0.545		
		SAF4	3.40	1.053	0.752	16.554	0.566		
		PE1	3.68	0.980	0.759	-	0.576	0.574	0.904
		PE2	3.71	0.966	0.731	17.770	0.535		
		PE3	3.80	0.987	0.747	18.037	0.559		
Positive Emotion	0.904	PE4	3.85	0.984	0.779	18.494	0.607		
		PE5	3.79	0.964	0.765	18.082	0.586		
		PE6	3.81	0.996	0.771	18.495	0.594		
		PE7	3.76	0.975	0.748	17.923	0.559		
		ENG1	3.84	1.108	0.795	-	0.633		
		ENG2	3.78	1.038	0.717	17.736	0.514	0.585	0.876
	0.875	ENG3	3.72	0.988	0.720	17.530	0.519		
Engagement		ENG4	3.87	1.092	0.796	19.989	0.633		
		ENG5	3.87	1.005	0.793	19.965	0.629		
		REL1	3.64	1.130	0.760	-	0.578	0.595	0.880
		REL2	3.70	1.126	0.820	19.784	0.673		
Relationship	0.889	REL3	3.75	1.133	0.789	18.578	0.622		
		REL4	3.56	0.999	0.721	16.952	0.521		
		REL6	3.61	1.039	0.763	18.310	0.583		
		MEA1	3.86	0.911	0.779	-	0.607	0.604	0.884
Meaning	0.881	MEA2	4.02	0.944	0.738	17.782	0.544		
		MEA3	3.95	0.896	0.710	17.112	0.504		

		MEA4	3.89	0.934	0.797	19.958	0.635		
		MEA5	3.94	0.959	0.853	20.935	0.728		
Achievement	0.774	ACH1	4.04	0.914	0.772	-	0.596	0.534	0.774
		ACH2	3.90	0.918	0.706	13.082	0.498		
		ACH6	3.87	0.959	0.712	12.975	0.507		

For the correlation coefficients, the maximum shared variance (MSV) and average shared variance (ASV) tend to be used to assess discriminant validity. To specify, the threshold for MSV and ASV values should be less than the AVE value [57]. The results of Table 12 show that, in the current study, all the AVE values are above the MSV and ASV values, suggesting that the eight constructs achieved satisfactory discriminant validity.

Table 12. Correlation and discriminant validity of the perceived benefits scale.

Construct	CR	AVE	MSV	ASV	IND	HEA	SAF	PE	ENG	REL	MEA	ACH
IND	0.877	0.584	0.379	0.170	0.764							
HEA	0.905	0.657	0.429	0.219	0.530***	0.810						
SAF	0.811	0.597	0.294	0.130	0.258***	0.357***	0.766					
PE	0.905	0.574	0.212	0.117	0.445***	0.393***	0.208***	0.757				
ENG	0.877	0.585	0.366	0.209	0.369***	0.570***	0.542***	0.288***	0.765			
REL	0.880	0.595	0.429	0.215	0.616***	0.655***	0.342***	0.460***	0.461***	0.771		
MEA	0.884	0.604	0.366	0.174	0.353***	0.427***	0.508***	0.347***	0.605***	0.361***	0.777	
ACH	0.774	0.534	0.045	0.121	0.083***	0.188***	0.076***	0.102	0.212***	0.149***	0.192***	0.731

Note: IND represents Independence; HEA represents Healthcare; SAF represents Safety; PE represents Positive Emotion; ENG represents Engagement; REL represents Relationship; MEA represents Meaning; ACH represents Achievement; *** $p < 0.01$.

4.5.3.2 Convergent and discriminant validity of perceived cost

Confirmatory factory analysis was conducted to determine the convergent and discriminant validity of the perceived cost scale. For convergent validity, the standardized factor loadings should be above the threshold 0.5 or above, C.R. (t-value) should be above the threshold 2 or above, and the averaged variances expected (AVE) value should also be above the threshold 0.5 or above [57]. Table 13 shows that the C.R. (t-value), standardized factor loadings, and AVE achieved adequate values.

Table 13. Convergent and discriminant validity of the perceived cost scale.

Construct	Cronbach's Alpha	Variable	Mean	Standard Deviation	Standardized Factor Loading	C.R. (t-Value)	SMC	AVE	Composite Reliability
Monetary Cost	0.897	MON1	3.60	1.057	0.762	-	0.581	0.636	0.897
		MON2	3.68	1.123	0.802	19.629	0.644		
		MON3	3.67	1.078	0.834	20.412	0.696		
		MON4	3.63	1.104	0.794	19.243	0.631		
		MON5	3.68	1.129	0.795	19.314	0.631		
Study	0.905	STU1	4.16	1.093	0.812	-	0.659	0.617	0.906

Cost		STU2	3.78	1.070	0.772	20.392	0.595		
		STU3	3.77	1.020	0.733	19.029	0.537		
		STU4	4.01	1.066	0.874	24.049	0.764		
		STU5	3.76	1.071	0.773	20.297	0.597		
		STU6	3.82	1.000	0.741	19.331	0.549		
Space Cost	0.874	SPA1	3.66	0.920	0.789	-	0.622	0.638	0.876
		SPA2	3.92	1.041	0.772	19.070	0.596		
		SPA3	3.72	0.951	0.845	20.891	0.715		
		SPA4	3.72	0.968	0.788	19.081	0.621		

For the correlation coefficients, the maximum shared variance (MSV) and average shared variance (ASV) tend to be used to assess discriminant validity. To specify, the threshold for MSV and ASV values should be less than the AVE value [57]. The results of Table 14 show that, in the current study, all the AVE values are above the MSV and ASV values, suggesting that the four constructs achieved satisfactory discriminant validity.

Table 14. Correlation and discriminant validity of the perceived benefits scale.

Construct	**CR**	**AVE**	**MSV**	**ASV**	**MON**	**STU**	**SPA**
MON	0.897	0.636	0.429	0.363	0.797		
STU	0.906	0.617	0.429	0.333	0.655***	0.785	
SPA	0.876	0.638	0.297	0.533	0.545***	0.486***	0.799

Note: MON represents Monetary Cost; STU represents Study Cost; SPA represents Space Cost; *** $p < 0.01$.

4.6 Conclusion and discussion

As one of the most promising areas of the Internet of Things, smart home will have important applications in dealing with the aging society issues and the healthcare challenges of older adults in the future. The design and development of smart homes for older adults should aim at realizing all-around happiness of the elderly, improving their quality of life both physically and psychologically to help them achieving independent, safe and happy life in old stage. For Chinese aging group, the current "new elders" is completely different from our previous impressions about the old people. They have strong enthusiasm about life, are willing to embrace new things, and are inextricably linked to the Internet. The biggest problem for the elderly is that with the decline of physical and social functions, their connection with family, society, and the outside world is not only degraded in physical aspect, but also psychologically. Therefore, the design and development of smart home products, services and platforms for the elderly should not only focus on their basic needs like clothing, eating, housing, moving, using and healthcare, but also satisfy their psychological and cognitive demand to help them maintain a good mental state and live a happy life.

In this chapter, the author conducted scale development on the perceived value of smart homes for the elderly. The scale mainly includes two parts, one is the perceived benefit scale and the other is the perceived cost scale. From the questionnaire survey and data analysis results, the variables and corresponding measurement items proposed in this chapter have all been verified. This chapter introduces the PERMA-V wellbeing model proposed by Seligman, the father of positive psychology, into the perceived value scale development of smart homes for older adults. Based on the concept of constructing a smart home for the elderly toward all-around wellbeing, this chapter clarified the dimensions, factor composition and relevant measurement items of perceived value through literature analysis, user interviews and expert interviews. Moreover, a perceived value scale of smart homes for the elderly with a comprehensive sense of wellbeing has been developed through the process of pre-study, exploratory factor analysis, confirmatory factor analysis, convergent and discriminant validity. To be more specific, the perceived value scale is mainly composed of two aspects: the perceived benefit scale and the perceived cost scale. The perceived benefit is divided into eight sub-dimensions, namely "Independence (IND)", "Healthcare (HEA)", "Safety (SAF)", "Positive Emotion (PE)", "Engagement (ENG)", "Relationship (REL)", "Meaning (MEA)" and "Achievement (ACH)". Perceived cost is divided into three sub-dimensions, namely "Monetary cost (MON)", "Study cost (STU)" and "Space cost (SPA)". The overall perceived value of smart homes is determined by perceived benefit and perceived cost. Therefore, the enlightenment for researchers and related practitioners is that if the perceived value of smart homes for the elderly want to be maximized, the smart home system should try to satisfy the elderly needs as much as possible at the eight different dimensions of perceived benefit. At the same time, it is necessary to control and reduce the perceived cost of smart homes for the elderly in the three dimensions. This is a complex and comprehensive system project that requires the organic coordination and overall planning of financial, material, technological, and human resources. The following is a detailed discussion for different dimensions:

- **Independence:** For the benefit of "independence", the final observed variables include five items, they are IND1, IND2, IND3, IND4, and IND6, their factor loadings are 0.813, 0.727, 0.784,0.739, and 0.755 which are all higher than 0.5. The Cronbach's α of these five measurements is 0.875>0.7, the AVE is 0.584>0.5, the Composite Reliability is 0.875>0.7. The related key indexes all present adequate value which reveals that the five items of the "Independence" dimension achieve satisfactory reliability and validity. The result shows that smart homes should aims at bringing efficiency and convenience to healthy or mildly disabled elders through smart products and services to help them get rid of dependence on others, achieve self-reliance, self-management, self-care, compensate for their waken ability to make them live with dignity. Smart home can insert nursing system to serve the elderly who bear mild disability or short-term disability, but could still live a home life with the help of equipment and light manpower assistance from the third-party platforms, organizations or short-term personnel care rather than going to specific elderly care institution. Older adults with chronic diseases are included in the discussion. However, those who get a serious illness or are seriously disabled or totally lose their mobility or selfcare ability are not taken into consideration in this research, because these kinds of people they could not live in their own house but need special care and living in hospital or specific elderly care institution.

- **Healthcare:** For the benefit of "healthcare", the final observed variables include five items, they are HEA1, HEA2, HEA4, HEA6, and HEA7, their factor loadings are 0.880, 0.762, 0.762,0.749, and 0.887 which are all higher than 0.5. The Cronbach's α of these five measurements is 0.903>0.7, the AVE is 0.657>0.5, the Composite Reliability is 0.905>0.7. The related key indexes all present adequate value which reveals that the five items of the "Healthcare" dimension achieve satisfactory reliability and validity. The result shows that smart homes should help the elderly realize the management, prevention, treatment and rehabilitation of healthy problems and diseases in home environment to live a healthy lifestyle through smart products and services. It includes the detection and management of physical health through smart medical equipment, embedded fitness equipment, telemedicine, rehabilitation training equipment, online medical consultation, etc.

- **Safety:** For the benefit of "healthcare", the final observed variables include three items, they are SAF1, SAF3, and SAF4, their factor loadings are 0.807, 0.738, and 0.752 which are all higher than 0.5. The Cronbach's α of these three measurements is 0.809>0.7, the AVE is 0.587>0.5, the Composite Reliability is 0.810>0.7. The related key indexes all present adequate value which reveals that the three items of the "Safety" dimension achieve satisfactory reliability and validity. The result shows that smart homes should ensure the physical safety, environmental safety, and property safety of the elderly through smart products and services. Among them, the physical safety of the elderly could be reflected by the emergency detection and responses, such as sudden heart attacks, falls, etc. Environmental safety could be reflected by the monitor of air, water, electricity, fire, etc. in the home environment to prevent accidents such as gas leak and fire disaster. Property safety could be mainly ensured via the anti-theft monitoring system through smart doors, windows, cameras, etc.
- **Positive Emotion:** For the benefit of "positive emotion", the final observed variables include seven items, they are PE1, PE2, PE3, PE4, PE5, PE6 and PE7, their factor loadings are 0.759, 0.731, 0.747,0.779, 0.765,0.771, and 0.748 which are all higher than 0.5. The Cronbach's α of these seven measurements is 0.904>0.7, the AVE is 0.574>0.5, the Composite Reliability is 0.904>0.7. The related key indexes all present adequate value which reveals that the seven items of the "Positive Emotion" dimension achieve satisfactory reliability and validity. The result shows that smart homes should help the elderly maintain good emotions status through smart products and services, making them feel comfortable, relaxed, calm, joyful, delighted, excited, loved, and get rid of negative emotions such as loneliness or depression. It could be mainly realized from two aspects. On the one hand, smart home could integrate lighting systems, temperature and humidity control systems, door and window systems, etc. to regulate the lighting, temperature, and humidity control to create a comfortable living environment for the elderly. On the other hand, smart home could provide smart home theater, smart game equipment, smart party system, etc. to enable the elderly to engage in different entertainment and social activities, such as listening to music and radio, watching TV series, watching movies, playing chess and card games, family gatherings, etc.
- **Engagement:** For the benefit of "engagement", the final observed variables include five items, they are ENG1, ENG2, ENG3, ENG4, and ENG5, their factor loadings are 0.795, 0.717, 0.720,0.796, and 0.793 which are all higher than 0.5. The Cronbach's α of these five measurements is 0.875>0.7, the AVE is 0.585>0.5, the Composite Reliability is 0.876>0.7. The related key indexes all present adequate value which reveals that the five items of the "Engagement" dimension achieve satisfactory reliability and validity. The result shows that smart homes should help the elderly to engage in activities related to their hobbies and competence in home life through smart products and services. The elderly could enter a state of "heart flow", forgetting time and space, and feel unparalleled happiness from the things they are engaged in. The shaping of engagement could mainly include intelligent information system, intelligent education system, intelligent interest assistance system, etc.,

to help the elderly master, learn and engage in knowledge and activities that they are interested in.

- **Relationship:** For the benefit of "relationship", the final observed variables include five items, they are REL1, REL2, REL3, REL4, and REL6, their factor loadings are 0.760, 0.820, 0.789,0.721, and 0.763 which are all higher than 0.5. The Cronbach's α of these five measurements is 0.889>0.7, the AVE is 0.585>0.5, the Composite Reliability is 0.880>0.7. The related key indexes all present adequate value which reveals that the five items of the "Relationship" dimension achieve satisfactory reliability and validity. The result shows that smart homes should help the elderly develop and strengthen their interpersonal bond with the outside world and promote their social interaction through smart products and services. The main objects may include their relatives, friends, families, children, couple, pets, related organizations and institutions. Moreover, it could also include the enhancement of the belief or religious connection of the elderly, the development of social companion robots based on artificial intelligence technology, and even the connection with nature through surroundings or the use of virtual reality to enhance their experience about the virtual nature.
- **Meaning:** For the benefit of "meaning", the final observed variables include five items, they are MEA1, MEA2, MEA3, MEA4, and MEA5, their factor loadings are 0.779, 0.738, 0.710,0.797, and 0.853 which are all higher than 0.5. The Cronbach's α of these five measurements is 0.881>0.7, the AVE is 0.604>0.5, the Composite Reliability is 0.884>0.7. The related key indexes all present adequate value which reveals that the five items of the "Meaning" dimension achieve satisfactory reliability and validity. The result shows that smart homes should help the elderly to find the purpose and direction of life, provide opportunity to allow them continue making social contribution or reemployment to realize their value of existence after retirement. For example, using the Internet technology and platform to help them achieve re-employment, do freelance work, create start-ups, join online volunteer community to contribute to society, provide remote peers support, help children take care of their grandchildren, master knowledge and skills through online study to complete unfulfilled wishes, etc.
- **Achievement:** For the benefit of "achievement", the final observed variables include three items, they are ACH1, ACH2, and ACH6, their factor loadings are 0.772, 0.706, and 0.712 which are all higher than 0.5. The Cronbach's α of these three measurements is 0.774>0.7, the AVE is 0.534>0.5, the Composite Reliability is 0.774>0.7. The related key indexes all present adequate value which reveals that the three items of the "Achievement" dimension achieve satisfactory reliability and validity. The result shows that smart homes should help the elderly to accomplish what they can do to make progress in their life, achieve their goal and gain a sense of accomplishment, not only provide more opportunities, but also enhance the feedback of the sense of achievement. It can be considered from the sense of reality achievement and virtual achievement. The sense of reality achievement may include helping the elderly to be appreciated, concerned, and gain the recognition and respect from others or acquire social status through their hobbies, talents, works, etc. The sense of virtual achievement may be mainly reflected in the smart home helping the elderly to get likes, comments, fans, and attention on the Internet platform or social media, even in virtual game system to obtain high rank of game character or virtual gaming wealth, etc.

- **Monetary Cost:** For the "monetary cost", the final observed variables include five items. the final observed variables include five items, they are MON1, MON2, MON3, MON4, and MON6, their factor loadings are 0.762, 0.802, 0.834,0.794, and 0.795 which are all higher than 0.5. The Cronbach's α of these five measurements is 0.897>0.7, the AVE is 0.636>0.5, the Composite Reliability is 0.897>0.7. The related key indexes all present adequate value which reveals that the five items of the "Monetary Cost" dimension achieve satisfactory reliability and validity. The result shows that the "monetary cost" of smart home mainly includes the purchase cost of related products, services and accessories, transportation fee, installation fee, usage fee, maintenance fee, etc. The price of smart home products and services should take the elderly's economic ability into consideration and enable the vast majority of elderly groups can afford them. Therefore, in the process of designing, developing and delivering related products and services, cost factors should be considered in every process to reduce the corresponding monetary expenditures.
- **Study Cost:** For the "study cost", the final observed variables include six items, they are STU1, STU2, STU3, STU4, STU5, and STU6, their factor loadings are 0.812, 0.772, 0.733, 0.874, 0.773 and 0.741 which are all higher than 0.5. The Cronbach's α of these six measurements is 0.905>0.7, the AVE is 0.617>0.5, the Composite Reliability is 0.906>0.7. The related key indexes all present adequate value which reveals that the six items of the "Study Cost" dimension achieve satisfactory reliability and validity. Nowadays, technology and knowledge are updated too quickly. Due to the decline of visual ability, hearing ability, language ability, and mobility, the cognition of the elderly are increasingly weakened. Their feelings are relatively slow down and are difficult to accept fresh things. They have formed their own operating habits and cognitive logic in the past decades and could not carry out too complicated operating activities. Therefore, the design and development of smart home for the elderly should start from their cognitive characteristics and operating habits to improve the ease of use of relevant products and services to reduce their time, money, energy, relationship and intelligence investment as much as possible.
- **Space Cost:** For the "space cost", the final observed variables include four items, they are SPA1, SPA2, SPA3, and SPA4, their factor loadings are 0.789, 0.772, 0.845, and 0.788 which are all higher than 0.5. The Cronbach's α of these four measurements is 0.874>0.7, the AVE is 0.638>0.5, the Composite Reliability is 0.876>0.7. The related key indexes all present adequate value which reveals that the four items of the "Space cost" dimension achieve satisfactory reliability and validity. The result shows that "Space cost" includes the rearrangement of the house, re-decoration, discarding of old equipment and furniture, and change of network layout. Thus, the related cost should be controlled from these four aspects, for example, maximum the usage of the old equipment, appliances and furniture resources, integrate new products with the existing house environment and decoration, etc.

References

1. Churchill Jr, G.A. A paradigm for developing better measures of marketing constructs. Journal of marketing research 1979, 16, 64-73.
2. DeVellis, R.F. Scale development: Theory and applications; Sage publications: 2016; Volume 26.
3. Gerbing, D.W.; Anderson, J.C. An updated paradigm for scale development incorporating unidimensionality and its assessment. Journal of marketing research 1988, 25, 186-192.
4. Zeithaml, V.A. Consumer perceptions of price, quality, and value: a means-end model and synthesis of evidence. Journal of marketing 1988, 52, 2-22.
5. Day, E.; Crask, M. Value assessment: the antecedent of customer satisfaction. Journal of Consumer Satisfaction, Dissatisfaction and Complaining Behavior 2000, 13.
6. Woodruff, R.B. Customer value: the next source for competitive advantage. Journal of the academy of marketing science 1997, 25, 139-153.
7. Noble, S.M.; Griffith, D.A.; Weinberger, M.G. Consumer derived utilitarian value and channel utilization in a multi-channel retail context. Journal of Business Research 2005, 58, 1643-1651.
8. Holbrook, M.B.; Schindler, R.M. Market segmentation based on age and attitude toward the past: Concepts, methods, and findings concerning nostalgic influences on customer tastes. Journal of Business Research 1996, 37, 27-39.
9. Sheth, J.N.; Newman, B.I.; Gross, B.L. Why we buy what we buy: A theory of consumption values. Journal of business research 1991, 22, 159-170.
10. Zhang, Q.; Li, M.Y.; Wu, Y.J. Smart home for elderly care: development and challenges in China. Bmc Geriatrics 2020, 20, doi:10.1186/s12877-020-01737-y.
11. Peek, S.T.M.; Aarts, S.; Wouters, E.J.M. Can smart home technology deliver on the promise of independent living? A critical reflection based on the perspectives of older adults. In Handbook of Smart Homes, Health Care and Well-Being; 2016; pp. 203-214.
12. Dewsbury, G.; Clarke, K.; Rouncefield, M.; Sommerville, I.; Taylor, B.; Edge, M. Designing acceptable 'smart' home technology to support people in the home. Technology and Disability 2003, 15, 191-199, doi:10.3233/tad-2003-15305.
13. Vanus, J.; Koziorek, J.; Hercik, R. Design of a smart building control with view to the senior citizens' needs. In Proceedings of the IFAC Proceedings Volumes (IFAC-PapersOnline), 2013; pp. 422-427.
14. Rossi, L.; Belli, A.; Santis, A.D.; Diamantini, C.; Frontoni, E.; Gambi, E.; Palma, L.; Pernini, L.; Pierleoni, P.; Potena, D.; et al. Interoperability issues among smart home technological frameworks. In Proceedings of the 2014 IEEE/ASME 10th International Conference on Mechatronic and Embedded Systems and Applications (MESA), 10-12 Sept. 2014, 2014; pp. 1-7.
15. Valera, A.; Lee, P.; Tan, H.P.; Tan, H.X.; Liang, H. Real world, large scale iot systems for community eldercare: Experiences and lessons learned. In Elderly Care: Options, Challenges and Trends; 2018; pp. 53-80.
16. Taiwo, O.; Gabralla, L.A.; Ezugwu, A.E. Smart Home Automation: Taxonomy, Composition, Challenges and Future Direction. Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics) 2020, 12254 LNCS, 878-894, doi:10.1007/978-3-030-58817-5_62.

17. Kudzai, M.; Cilliers, L. Mitigating the elderly's privacy concerns when making use of Mobile Monitoring and Care systems. In Proceedings of the 2016 IST-Africa Conference, IST-Africa 2016, 2016.
18. Lê, Q.; Nguyen, H.B.; Barnett, T. Smart Homes for Older People: Positive Aging in a Digital World. Future Internet 2012, 4, 607-617, doi:10.3390/fi4020607.
19. Wilkowska, W.; Ziefle, M. User diversity as a challenge for the integration of medical technology into future smart home environments. In User-Driven Healthcare: Concepts, Methodologies, Tools, and Applications; 2013; Volume 2, pp. 553-582.
20. Ghorayeb, A.; Comber, R.; Gooberman-Hill, R. Older adults' perspectives of smart home technology: Are we developing the technology that older people want? International Journal of Human Computer Studies 2021, 147, doi:10.1016/j.ijhcs.2020.102571.
21. Pal, D.; Arpnikanondt, C.; Funilkul, S.; Razzaque, M.A. Analyzing the adoption and diffusion of voice-enabled smart-home systems: empirical evidence from Thailand. Universal Access in the Information Society, doi:10.1007/s10209-020-00754-3.
22. Zwierenberg, E.; Finnema, E.; Dijkstra, A.; Hagedoorn, M.; Sanderman, R. Diffusion of assistive technology among older people: A case of the House of the Present. Gerontechnology 2018, 16, 242-248, doi:10.4017/GT.2017.16.4.006.00.
23. Grace, S.L.; Taherzadeh, G.; Chang, I.S.J.; Boger, J.; Arcelus, A.; Mak, S.; Chessex, C.; Mihailidis, A. Perceptions of seniors with heart failure regarding autonomous zero-effort monitoring of physiological parameters in the smart-home environment. Heart & Lung 2017, 46, 313-319, doi:10.1016/j.hrtlng.2017.04.007.
24. Gaul, S.; Ziefle, M. Smart Home Technologies: Insights into Generation-Specific Acceptance Motives. In Hci and Usability for E-Inclusion, Proceedings, Holzinger, A., Miesenberger, K., Eds.; Lecture Notes in Computer Science; 2009; Volume 5889, pp. 312-332.
25. Rodrigues, N.; Pereira, A. A user-centred wellbeing home for the elderly. Applied Sciences (Switzerland) 2018, 8, doi:10.3390/app8060850.
26. Yu, J.; de Antonio, A.; Villalba-Mora, E. Older adult segmentation according to residentially-based lifestyles and analysis of their needs for smart home functions. International Journal of Environmental Research and Public Health 2020, 17, 1-21, doi:10.3390/ijerph17228492.
27. Offermann-van Heek, J.; Ziefle, M. Nothing Else Matters! Trade-Offs Between Perceived Benefits and Barriers of AAL Technology Usage. Frontiers in Public Health 2019, 7, doi:10.3389/fpubh.2019.00134.
28. Mehrabian, S.; Extra, J.; Wu, Y.H.; Pino, M.; Traykov, L.; Rigaud, A.S. The perceptions of cognitively impaired patients and their caregivers of a home telecare system. Medical Devices-Evidence and Research 2015, 8, 21-29, doi:10.2147/mder.S70520.
29. Singh, D.; Psychoula, I.; Kropf, J.; Hanke, S.; Holzinger, A. Users’ perceptions and attitudes towards smart home technologies. Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics) 2018, 10898 LNCS, 203-214, doi:10.1007/978-3-319-94523-1_18.
30. Stefanov, D.H.; Zeungnam, B.; Won-Chul, B. The smart house for older persons and persons with physical disabilities: structure, technology arrangements, and perspectives. IEEE Transactions on Neural Systems and Rehabilitation Engineering 2004, 12, 228-250, doi:10.1109/TNSRE.2004.828423.

31. Thielke, S.; Harniss, M.; Thompson, H.; Patel, S.; Demiris, G.; Johnson, K. Maslow's Hierarchy of Human Needs and the Adoption of Health-Related Technologies for Older Adults. Ageing International 2012, 37, 470-488, doi:10.1007/s12126-011-9121-4.
32. Liu, Y.Q.; Tamura, R.; Song, Y. Constructing a Smart Home for Future Elders toward All-around Happiness: Taking Connectivity as the Core Element. Applied Sciences-Basel 2020, 10, doi:10.3390/app10165690.
33. Jusob, F.R.; George, C.; Mapp, G. Exploring the need for a suitable privacy framework for mHealth when managing chronic diseases. Journal of Reliable Intelligent Environments 2017, 3, 243-256, doi:10.1007/s40860-017-0049-7.
34. Astell, A.J.; McGrath, C.; Dove, E. 'That's for old so and so's!': does identity influence older adults' technology adoption decisions? Ageing & Society 2020, 40, 1550-1576, doi:10.1017/s0144686x19000230.
35. Majumder, S.; Aghayi, E.; Noferesti, M.; Memarzadeh-Tehran, H.; Mondal, T.; Pang, Z.; Deen, M.J. Smart Homes for Elderly Healthcare-Recent Advances and Research Challenges. Sensors 2017, 17, doi:10.3390/s17112496.
36. Ding, D.; Cooper, R.A.; Pasquina, P.F.; Fici-Pasquina, L. Sensor technology for smart homes. Maturitas 2011, 69, 131-136, doi:10.1016/j.maturitas.2011.03.016.
37. Melyani; Meyliana; Prabowo, H.; Hidayanto, A.N.; Gaol, F.L. Smart Home Component using Orange Technology for Elderly people: A Systematic Literature. In Proceedings of the 2018 Indonesian Association for Pattern Recognition International Conference (INAPR), 7-8 Sept. 2018, 2018; pp. 166-171.
38. Lee, L.; Kim, M.J. A Critical Review of Smart Residential Environments for Older Adults With a Focus on Pleasurable Experience. Frontiers in Psychology 2020, 10, doi:10.3389/fpsyg.2019.03080.
39. Nagapuri, S.; Maeder, A.J.; Williams, P.A.H. Health smart homes: User perspectives. Studies in Health Technology and Informatics 2019, 266, 127-135, doi:10.3233/SHTI190784.
40. Turjamaa, R.; Pehkonen, A.; Kangasniemi, M. How smart homes are used to support older people: An integrative review. International Journal of Older People Nursing 2019, 14, doi:10.1111/opn.12260.
41. Liu, L.; Stroulia, E.; Nikolaidis, I.; Miguel-Cruz, A.; Rios Rincon, A. Smart homes and home health monitoring technologies for older adults: A systematic review. International Journal of Medical Informatics 2016, 91, 44-59, doi:10.1016/j.ijmedinf.2016.04.007.
42. Pal, D.; Triyason, T.; Funilkul, S.; Ieee. Smart Homes and Quality of Life for the Elderly: A Systematic Review; 2017; pp. 413-419.
43. Demiris, G.; Hensel, B.K. Technologies for an aging society: a systematic review of "smart home" applications. Yearbook of medical informatics 2008, 33-40, doi:10.1055/s-0038-1638580.
44. Lee, E.J.; Park, S.J. A framework of smart-home service for elderly's biophilic experience. Sustainability (Switzerland) 2020, 12, 1-26, doi:10.3390/su12208572.
45. Sepasgozar, S.; Karimi, R.; Farahzadi, L.; Moezzi, F.; Shirowzhan, S.; Ebrahimzadeh, S.M.; Hui, F.; Aye, L. A Systematic Content Review of Artificial Intelligence and the Internet of Things Applications in Smart Home. Applied Sciences-Basel 2020, 10, doi:10.3390/app10093074.
46. Marikyan, D.; Papagiannidis, S.; Alamanos, E. A systematic review of the smart home

literature: A user perspective. Technological Forecasting and Social Change 2019, 138, 139-154, doi:10.1016/j.techfore.2018.08.015.

47. Kon, B.; Lam, A.; Chan, J. Evolution of smart homes for the elderly. In Proceedings of the 26th International World Wide Web Conference 2017, WWW 2017 Companion, 2019; pp. 1095-1101.
48. Lussier, M.; Adam, S.; Chikhaoui, B.; Consel, C.; Gagnon, M.; Gilbert, B.; Giroux, S.; Guay, M.; Hudon, C.; Imbeault, H.; et al. Smart Home Technology: A New Approach for Performance Measurements of Activities of Daily Living and Prediction of Mild Cognitive Impairment in Older Adults. Journal of Alzheimer's Disease 2019, 68, 85-96, doi:10.3233/JAD-180652.
49. Lee, R.C. The new way of social connecting for the elderly through smart home applications. Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics) 2015, 9191, 142-152, doi:10.1007/978-3-319-20895-4_14.
50. Zimmermann, V.; Gerber, P.; Marky, K.; Böck, L.; Kirchbuchner, F. Assessing users' privacy and security concerns of smart home technologies. i-com 2020, 18, 197-216, doi:10.1515/icom-2019-0015.
51. Luor, T.T.; Lu, H.-P.; Yu, H.; Lu, Y. Exploring the critical quality attributes and models of smart homes. Maturitas 2015, 82, 377-386.
52. Kowalski, J.; Skorupska, K.; Kopeć, W.; Jaskulska, A.; Abramczuk, K.; Biele, C.; Marasek, K. Older adults and voice interaction: A pilot study with google home. In Proceedings of the Conference on Human Factors in Computing Systems - Proceedings, 2019.
53. Schroeter, C.; Mueller, S.; Volkhardt, M.; Einhorn, E.; Huijnen, C.; Heuvel, H.v.d.; Berlo, A.v.; Bley, A.; Gross, H. Realization and user evaluation of a companion robot for people with mild cognitive impairments. In Proceedings of the 2013 IEEE International Conference on Robotics and Automation, 6-10 May 2013, 2013; pp. 1153-1159.
54. Tabachnick, B.G.; Fidell, L.S. Using multivariate statistics . Northridge. Cal.: Harper Collins 1996.
55. Gratz, K.L.; Roemer, L. Multidimensional assessment of emotion regulation and dysregulation: Development, factor structure, and initial validation of the difficulties in emotion regulation scale. Journal of psychopathology and behavioral assessment 2004, 26, 41-54.
56. Woosnam PhD, K.M.; Norman PhD, W.C. Scale Development and Factor Structure Confirmation of Constructs within Durkheim's Theoretical Framework of Emotional Solidarity. 2016.
57. Fornell, C.; Larcker, D.F. Evaluating structural equation models with unobservable variables and measurement error. Journal of marketing research 1981, 18, 39-50.

Chapter 5
Perceived risk scale of smart homes for the elderly

Chapter 5
Perceived risk scale of smart homes for the elderly

5.1 Research purpose

This chapter taking the Chinese social and cultural background, the development status of smart home industry in China and the characteristics of future elderly into consideration, aims at developing a perceived risk scale of smart homes for future elderly from a macro perspective to a micro perspective. The scale will comprehensively reflect older adults' barriers and perception of risk about the adoption of smart homes and provide risk evaluation criteria from a customer-oriented aspect. It can help the designers, developers, and practitioners identify, reduce, control and avoid associated risks during the design, development, and delivery of the smart home products and services for the elderly which presents crucial theoretical and practical significance.

5.2 Research method

This chapter follows the standard scale development and validation process [1-3]. First, a preliminary pool of measurement items of perceived risk was formed through literature research and user interview. Second, an expert interview was conducted to analyze the rationality of all the items, the item expressions were optimized, and relevant contents were refined. Third, a questionnaire was formulated using the optimized measurement items, and a pre-study was conducted to ensure the questions and answers were meaningful. Forth, the final questionnaire of the perceived risk of smart homes for the elderly was formed after modification and adjustment according to the analysis result of the pre-study. Fifth, the final questionnaire was used to conduct the main investigation, which includes data collection and analysis. The first-round data was used for exploratory factor analysis, SPSS 25.0 was applied to extract factors and test the validity of relevant factor loading. The second-round data was used for confirmatory factor analysis via AMOS 25.0. According to the data analysis result, the measurement items of the corresponding factors were optimized until all the model fit indexes reach the standard threshold. Last but not least, the constituent factors and measurement items which satisfy all the model fit index threshold was outputted to form the final scale.

5.3 Defining perceived risk of smart homes for the elderly

Perceived risk refers to the probability or possibility that the product estimated by the customers at the time of purchase will not meet their expectations [4]. Bauer first proposed the concept of perceived risk in 1960 [5]. He pointed out that perceived risk includes two connotations, one is the uncertainty probability of the result, another is the severity of the consequences if a decision is wrong. In 1967, Bauer further pointed out that individual perceived risk and actual risk are two completely different concepts. Perceived risk refers to the individual's subjective judgment on the risk of things; actual risk is the objective risk obtained after rigorous scientific evaluation [6].Cox defines perceived risk as a function of two factors, the first one is the individual estimates the probability that the purchase behavior may lead to adverse consequences before the purchase behavior occurs. The second one is the degree of loss felt by the individual when adverse consequences occur after the purchase behavior[7]. Cunninghan continued to make further modifications to Cox's function and tested it with empirical research, the perceived risk has been further typified as six dimensions, namely performance, financial, opportunity/time, safety, social and psychological loss[8]. Jacoby and Kaplan divided individual shopping risks into five categories, namely, social risks, health risks, psychological risks, performance risks, and financial risks [9]. The majority of literatures show that the individual's perceived risk variables are multi-dimensional. To sum up, based on the results of various researches, perceived risk can be basically summarized into seven types: healthy risk, psychological risk, financial risk, social risk, performance risk, time risk, and privacy risk [10-12] .

Considering the development status of China's smart home industry as well as the physical and psychological characteristics of the elderly in China, this chapter expands the basis of the perceived risk collected from the relevant literature to identify the preliminary risk dimensions of smart homes for the elderly. The definition of related dimensions is as following.

- **Privacy & Security risk:** The "Privacy & Security risk" refers to the non-autonomy, possible leakage or abuse of users' personal information and data due to the smart home system running or security issues during the process of monitoring user activities, health status and home environment.
- **Physical risk:** The "Physical risk" refers to the potential personal safety hazards and accident brought by smart home systems. It is mainly reflected in possible theft, robbery, blackmail and extortion, incorrect or untimely feedback of emergency, accidental injuries caused by equipment physical materials and shapes, invisible health problems caused by electromagnetic radiation, etc.
- **Technological risk:** The "Technological risk" refers to the risk which bringing by the immaturity, instability, inflexibility and incompatibility of smart home technology. It is mainly reflected in the low accuracy to recognize and conduct user commands, low system stability, system failures, false alarms, low expansion capability, incompatibility between different products and operating systems, poor data management and treatment ability, etc.
- **Performance risk:** The "Performance risk" refers to the function design, appearance design, interaction design, user experience design, etc. of the smart home system, do not fully consider the actual needs, operating habits, life routine, individual feelings of the elderly users. It is mainly reflected in the unitary and poor usability, obstruction or impediment devices, aesthetic incongruence with the home environment, low accessibility and unfriendly operation, interference with daily activities, etc.
- **Service risk:** The "Service risk" refers to the smart home services cannot meet the elderly's demand and present low service quality. It is mainly reflected in low service reliability, no timely response, no enough quality assurance, no consistency commercial promise, unprofessional and incompetent service staffs, etc.
- **Financial risk:** The "Financial risk" refers to the pressure and uncertainty that users feel for their financial cost during the process of purchasing, using, and maintaining smart home products and services. It is mainly reflected in the relevant products and services

are beyond the affordability of the elders, there is non-essential financial expenditure, the money spent doesn’t deserve its value, etc.

- **Psychological risk:** The "Psychological risk” refers to the pressure of external opinions and internal psychological barriers that users feel during the process of purchasing and using the smart home system. It is mainly reflected in the blame and incomprehension from important persons, unhealthy reliance on automation technology and loss of autonomy, persistent reminder about self-frailty, etc.
- **Industry & Market risk:** The "Industry and market risk” refers to the risk of immature and irregular market and industry development of smart homes for the elderly. It is mainly reflected in the market penetrations stays low and are far from mass adoption, no consistency industry standardization and regulation, no eligibility criteria about the products and services quality, the compatibility of different brands and products is poor, etc.
- **Social support risk:** The "Social support risk” mainly exists in the situation that the implementation of smart home products and systems need relevant social resources and forces, such as family support, peer support, community support, neighborhood assistance, institutional assistance, telemedicine services, emergency response etc., The lack of these kinds of support will bring relevant social support risk.
- **Policy & law risk:** The "Policy & law risk” refers to the government or relevant public department and authorities that have not promulgated and issued effective policies and laws to regulate the smart home industry and provide guarantees for serving consumers. It is mainly reflected in the lack of legal framework, standards and guidance as well as immature policy & law conduction and supervision environment.

5.4 Preliminary works

5.4.1 Items generation

In order to give a convincing and systematic review about the risk and barrier of smart home for elderly. The author has searched the global mainstream literature databases, including Web of science, Scopus, IEEE Xplore, with keywords "smart home", "older adult", "perception" and their synonyms. 2110 articles were collected in total. The specific search results are shown in Table 1.

Table 1. Database, Search Terms and Hits

Database	Search Terms	Hits
Web of Science(1990-2020)	("smart home" OR "smart-home" OR "smart house" OR "remote house" OR "intelligent home" OR "intelligent house" OR "home automation system" OR "house automation system" OR "automated home" OR "automated house") AND ("older adult" OR "Elderly" OR "senior" OR "elder" OR "older person" OR "older people" OR "aged" OR "aging" OR "middle-aged") AND ("perception" OR "Adoption" OR "acceptance" OR "acceptability" OR "need" OR "demand" OR "requirement" OR "attitude" OR "behavior" OR "awareness" OR "willingness" OR "barrier" OR "difficulty" OR "assessment" OR "evaluation" OR "measurement" OR "measure")	473
Scopus(1990-2020)		1354
IEEE Xplore(1990-2020)		283

Among the 2110 articles, 852 duplicate articles were deleted, 59 unnamed articles were deleted, and the remaining 1199 articles were screened by title, abstract and full text. In the end, 64 articles were selected as the materials of literature review. From the existing articles, we refined and summarized keywords for the perceived risk of smart home for the elderly. After deleting and merging synonyms as well as adding some new keywords, the author has gained Table 2. The table shows the key components of perceived risk of smart homes for the elderly and synonyms are placed in brackets for similar components. Based on it, the initial measurement items of each dimension were generated. Then, a small range of user interview was conducted. The author randomly selected 15 future elderly people aged 45-60, and asked them about their understanding of the generated measurement items, as well as other possible risk that were not reflected or fully reflected in the existing variables and measurement items. According to their understanding and reflection, the language expression and content of each items have been modified and optimized. Some new items and content have been added. Through the literature review and user interview, the item pool of perceived risk of smart homes for future elderly has been formed.

Table 2. Measurement item categories, keywords, and references

Perceived Risk	Statements	Source
Privacy & Security risk (PS)	Surveillance(Feeling of surveillance Continuous monitoring) ; Personal daily life activities (Person detection and tracking, Violation of personal space); Poor health status ignorance (Avoidance of shame), Data accessibility and invisibility (Access control, Accessibility of data, System visibility to others, Personal health information, Privacy of information/data, access control, Anonymity, Invasion of personal information, Unauthorized access, Informed consent, Transfer of personal information to third parties potentially without proper consent, Forwarding data to third parties); Data ownership (Disclosure risks, Encryption, confidentiality, Ownership) ; Data misuse(Information misuse/abuse, Consent and uncertainty of H-IoT data), Loophole, Data autonomy (Loss of autonomy, Loss control)	[13-16] [17] [18] [19] [20] [21] [22] [23] [24] [25] [26] [27] [28] [29] [30] [31] [32] [33] [34] [35] [36] [37] [38] [39] [40] [41]
Physical risk (PHY)	Theft, Robbery, Blackmail and extortion, Physical hurt, Wrong command for harm, No timely help, Unexpected health problems (Decontextualization of health and well-being, Make less physically active),	[17] [22] [23] [24] [26] [30] [35] [37] [38]
Technology risk (TECH)	Low accuracy(Wrong command, False alarm, Technical failure, Accuracy and performance, Inaccurate measurement, Authentication), Fear of malfunction (Malfunction concerns), Inflexibility(Stubborn, Modularity), Feasibility(Architecture issues, Pattern recognition issues, Perceived hassle factor, Restriction in distance or time away from home, Complexity, assessment,), Low incompatibility(Incompatibility of devices, Integration issues, Compatible devices, Lack interoperability, Lack of interoperability among heterogeneous systems), Insufficient system reliability (Reliability, Lack of reliability in the sensor system, Loss connection, Sensor uncertainty management, long-term reliability, Lack of continuous monitoring), Expansion capability, , Stability(Robustness, General system stability, Risk of old-fashioned system),Lack of information to organize programs for the elderly(Continuous learning, prediction, recommendation and decision (AI-driven)) , Data management (Volume of data collection, Recording and storage of data, Data handling capability and compression techniques, Real-time data analysis, Salient summary generation from large amounts of sensory data).	[14,16,37] [42] [17] [18] [19] [21] [24] [25] [43] [27] [28] [29] [30] [31] [34] [35] [36] [37]
Performance risk (PER)	Usability (Perception of lack of usefulness, Poor usability, Usefulness, Functional dependence, Fully functional and comprehensive smart home, Additional demands, Adjustment to changing needs, Concern about future needs and abilities), Intrusiveness(Obstruction or impediment in space), Inconspicuousness(Accommodate differences across	[16,19] [20] [22] [23] [24] [25] [27] [34] [35] [36] [37]

	individuals and households ,Feelings of comfort with the design, Aesthetics, Aesthetic incongruence, Attractive design, Obtrusiveness), Accessibility (Subject personalization issues, Difficulty of introducing technology into the lives of the elderly), Ease to use (Account for front-end interfaces for elderly people and back-end interfaces for younger stakeholders, Lack of user friendliness or accessibility, Discomfort or strain, Excessive noise, Lack of general user involvement, Difficulties operating general technology currently used at home), Daily activities and routine disruption (Interference with daily activities, Disrupts daily routines, Acquisition of new rituals, Impact of the information on lifestyle);	
Service risk (SER)	Reliability (Unreliable services), Responsiveness (Lack of human response, No timely response, Lack of human response in emergencies), No assurance, Inconsistent services, Unsuitable services and products (Non-professional care, Inappropriate care, Unsuitable services and products, Insufficient demand, Lack of perceived need, Comfortability, Gap between designers and service provider), Personalized service, Incompetent stuffs(Bad manner stuff, Low neatness and cleanness, Empathy, Communication)	[14] [16] [21] [44] [45] [40]
Financial risk (FIN)	Affordability (Financial accessibility, Beyond affordability, High acquisition costs), Low value (Cost-effectiveness), Continuous money investment, Non-essential luxuries (Luxury market-oriented business models), Sustainability(Energy efficiency, Save money), Financial pressure	[14] [16] [18,42] [19] [21] [24] [25] [26] [27] [29] [32] [34] [35] [36] [37]
Psychological risk (PSY)	Family blame (Couple, Children, Relatives), Friends opposition(Impact on relationships, Detrimental effects on relationships), Cause of embarrassment or stigma, Burden to others, Social isolation (Isolation, Social stigmatization, Social-isolation due to an increased dependence on technology, Reduction of social relationships and interaction, Reduction of human contact, Threat to replace in-person visits), Over-reliance on technology (Fear of too much reliance, Increase dependence on technology, Replacing human care by technology), Autonomy (Loss of autonomy, the anxiety of being controlled, Lack of control over autonomously operating systems, Lose control of housekeeping, personal autonomy, Stigma and autonomy), Reinforcing an image of being 'old' (Hurt self-esteem, Dignity, Symbol of loss of independence), Resistance to using innovative technology (Exclusion, Mistrust, Uncertainty)	[15,19] [21] [23] [24] [26] [43] [27] [28] [29] [46] [34] [36] [37] [38] [39] [40] [41]
Industry & Market risk (IM)	Absence of a comprehensive market (Immaturity, Disorderly development, Constant assurance, Few maintenance), No consistency standardization and regulation (Lack of standardization, Newest technical standard, Uncertainty with regulation conflicts between smart home service providers and user) , Fast update (Obsolescence), Eligibility criteria	[14] [42] [20] [24] [25] [27] [38] [39] [41]

	(Approved manufacturer's label ,Seal of quality, Lack of trust in the manufacturer or provider of the system), Low compatibility, Shortage of service labor	
Social Support risk (SS)	Healthcare providers, Caregivers (Increase the dependency for caregivers, The degree to which smart homes lessen the sense of personal responsibility on the part of users or their caregivers must be weighed against associated benefits) Medical staff (Nurse, Clinicians), Medical experts (Increase dependence on outside experts), Family, Relatives, Friends, Neighborhood, Community, Organization and institution	[29] [39] [40] [40]
Policy & Law risk (PL)	Lack of policies & legal framework, Lack of policy & law conduct environment (Lack of comprehensive reimbursement policies), Lack of policy & law supervision environment, Lack of policy & law to provide right assurance, Lack of legal responsibilities and professional competence, Lack of legal aid	[25] [37] [41]

5.4.2 Refinement and item reduction

The item pool formed for perceived risk through literature research review and user interview contained 81 items. Among them, there were 8 items for Privacy & Security risk, 8 for Physical risk, 12 for Technological risk, 8 for Performance risk, 10 for Service risk, 5 for Financial risk, 8 for Psychological risk, 6 for Industry & Market risk, 10 for Social support risk, 6 for Policy & Law risk, 81 in total. After acquiring the item pool, expert interview was conducted to evaluate the rationality of each dimensions and each measurement items of perceived risk. A total of 10 experts participated in this research, including 4 PhD candidates and 3 Professors whose research field is aging group, 3 workers in the smart home industry. We use the mode of remote interviews through Tencent Conference and ZOOM to ask experts to present their opinions on the rationality, suitability, validity of each perceived risk dimensions and relevant measurement items. At the same time, the expression and meaning delivery of each items have also been emphasized. Due to their suggestions and advice, the author made modification of all the items which consider keeping, adding, deleting, merging, revising or dimensional adjustments. The final items for perceived risk were 7 items for Privacy & Security risk, 7 for Physical risk, 10 for Technological risk, 8 for Performance risk, 9 for Service risk, 5 for Financial risk, 7 for Psychological risk, 6 for Industry & Market risk, 10 for Social Support risk, 6 for Policy & Law risk, 75 in total. The detailed measurement items are shown in Table 3.

Table 3. The items of perceived risk scale

Perceived Risk	Label	Items
Privacy & Security risk (PS)	PS1	I don't like the feeling of surveillance.
	PS2	I don't like to share my personal daily life activities with others.
	PS3	I don't like to share my sensitive personal health information (PHI) data with my important person.
	PS4	I am worried about the ownership of my personal data and information.
	PS5	I am worried that the service provider of smart homes will misuse my personal data and information without my permission.
	PS6	I am worried about the unauthorized access to my personal data and information and for what purposed it is being used.
	PS7	I am worried that the smart homes system has loophole and might be attacked by hacker.
Physical risk (PHY)	PHY1	I am worried that using smart homes will increase the risk of theft.
	PHY2	I am worried that using smart homes will increase the risk of robbery.
	PHY3	I am worried that using smart homes will increase the risk of blackmail and extortion.
	PHY4	I am worried that some devices or equipment may be lack of reliable physical quality and hurt me.
	PHY5	I am worried that the smart homes may provide me wrong information or conduct wrong command and bring harm to me.
	PHY6	I am worried that when I encounter emergency problems the smart homes could not provide timely responses and help.
	PHY7	I am worried that the usage and radiation of smart homes will bring unexpected health problems.
Technology risk (TECH)	TECH1	I am worried that the smart homes system could not identify or conduct my command accurately.
	TECH2	I am worried that the smart homes may have malfunctions or suboptimal performance.
	TECH3	I am worried that the smart homes may lack of reliability in the system.
	TECH4	I am worried that the smart homes will deliver wrong messages to related people or service staff.
	TECH5	I am worried that the smart homes devices and systems may have low expansion capability.
	TECH6	I am worried that the smart homes may lack of interoperability among different devices and heterogeneous systems.
	TECH7	I am worried that the smart homes technology update too fast and old-fashioned system may have low stability.
	TECH8	I am worried that the smart homes are inflexibility.
	TECH9	I am worried that the smart homes should conduct continuous machine learning and may lack of data to organize programme for me.

	TECH10	I am worried that the data management (record, storage, handling capability and compression) techniques are immature.
Performance risk (PER)	PER1	I am worried that the smart homes function is too unitary and may have poor usability.
	PER2	I am worried that the smart homes devices are obstruction or impediment in space and make me feel uncomfortable at home.
	PER3	I am worried that the smart homes devices are aesthetic incongruence which cannot integrate with my house environment.
	PER4	I am worried that the smart homes devices and systems have low accessibility and are hard to use.
	PER5	I am worried that the smart homes interface and interaction is lack of user friendliness for elderly people.
	PER6	I am worried that the smart homes function could not meet my needs and demand as time goes by.
	PER7	I am worried that the smart homes have interference with my daily activities.
	PER8	I am worried that the smart homes may disrupt my daily routines.
Service risk (SER)	SER1	I am worried that the smart homes services are not reliable.
	SER2	I am worried that the smart homes services could not give me timely responses.
	SER3	I am worried that the smart homes services do not have assurance.
	SER4	I am worried that the smart homes services could not provide the consistent services according to their promise.
	SER5	I am worried that the smart homes services could not provide suitable and professional services.
	SER6	I am worried that the smart homes services could not provide personalized services I want.
	SER7	I am worried that the smart homes services staff could not treat me in a good manner.
	SER8	I am worried that the smart homes services staff is in low neatness and cleanness
	SER9	I am worried that the smart homes services staff could not understand my specific needs.
Financial risk (FIN)	FIN1	I am worried that the cost of smart homes products and services are beyond my affordability.
	FIN2	I am worried that the money I pay for smart homes doesn’t deserve its value.
	FIN3	I am worried that I will spend more money for its affordable services if I use smart homes.
	FIN4	I am worried that smart homes may bring me some non-essential financial expenditure.
	FIN5	I am worried that smart homes may increase my financial pressure.
Psychological risk (PSY)	PSY1	I am worried that my family will blame me on the usage of smart homes.
	PSY2	I am worried that my friends will think I am strange if I use smart homes.
	PSY3	I am worried that smart homes may cause of embarrassment or stigma when people visit my house.
	PSY4	I am worried that smart homes devices may be a burden to the people who live with me.

	PSY5	I am worried that smart homes may replace or diminish my human contact and result in social isolation.
	PSY6	I am worried that the smart homes will result in my reliance on automation technology and loss of autonomy
	PSY7	I am worried that the smart homes devices will always be perceived as reinforcing an image of being "old" for myself.
Industry & Market risk (IM)	IM1	I am worried that there is an absence of a comprehensive market.
	IM2	I am worried that there is no consistent standardization and regulation of the smart home industry.
	IM3	I am worried that the product update too fast and the products I brought would be obsolete soon.
	IM4	I am worried that there is no eligibility criteria about the enterprises and service providers' quality and level.
	IM5	I am worried that the compatibility of different brands, systems, devices is terrible.
	IM6	I am worried that there is a shortage of service labor in related aging industry.
Social Support risk (SS)	SS1	I am worried that if there is no enough support from healthcare providers.
	SS2	I am worried that there is no enough support from caregivers.
	SS3	I am worried that there is no enough support from medical staff.
	SS4	I am worried that there is no enough support from medical experts.
	SS5	I am worried that there is no enough support from my family.
	SS6	I am worried that there is no enough support from my relatives.
	SS7	I am worried that there is no enough support from my friends.
	SS8	I am worried that there is no enough support from my neighborhood.
	SS9	I am worried that there is no enough support from my community.
	SS10	I am worried that there is no enough support from organizations and institutions.
Policy& Law risk (PL)	PL1	I am worried that there is a lack of policy or legal framework to give the standards and guidance.
	PL2	I am worried that there is a lack of policy & law conduct environment.
	PL3	I am worried that there is a lack of policy & law supervision environment.
	PL4	I am worried that there is a lack of policy & law to provide right assurance.
	PL5	I am worried that there is a lack of legal responsibilities and professional competence of service providers and caregivers.
	PL6	I am worried that there is a lack of legal aid if some accident happened due to the technology or service problems.

5.4.3 Questionnaire design

After clarifying the dimensions of perceived risk and generating relevant measurement items, the author compiled a questionnaire including all the generated items. The questionnaire mainly consists of two parts. The first part is the demographic information of the survey respondents, including age, gender, occupation, monthly income, marital status; the second part is the perceived risk scale of smart homes for future elderly, see Appendix B. All the questions have been given a specific condition "When I am old" and all the items have been measured through 5-point Likert scale, during which "1" is "strongly disagree", "2" is "disagree", "3" is "general", "4" is "agree", and "5" "is "strongly agree".

5.4.4 Pre-study

Before starting large scale investigation, a pre-study was conducted to check the consistency, clarity and reliability of the questionnaire. The scale was formatted in a 5-point Likert scale and 68 middle-aged people aged from 45-60 were recruited in the pilot study. Depending on the data result, some confusing questions and long statement were accordingly modified. Accordingly, SPSS 25.0 was used to evaluate the consistency and reliability of the questionnaire. The Cronbach's α of the pilot study was 0.897, which was above the threshold of 0.7 and indicated that the questionnaire had satisfactory reliability.

5.5 Scale development and factor analysis

This section attempts to identify the measurement items of the perceived risk scale and examine the related reliability and validity of different constructs and measurements. Specifically, all 75 items for perceived risk were gathered to form a questionnaire and all the items are measured based on a 5-point Likert scale. Participants would respond to each item scale from 1=strongly disagree to 5=strongly agree. SPSS25.0 and AMOS 25.0 for Windows were used to conduct statistical analysis, the exploratory factor analysis (EFA) and confirmatory factor analysis (CFA) were used to test the distinctive constructs and model fit indices of the theoretical structure.

5.5.1 Exploratory factor analysis

Exploratory factor analysis (EFA) was conduct to reduce the dimensionality and explore the appropriate structure of the perceived risk scale.

5.5.1.1 Respondents

The author conducted an online questionnaire survey through Wenjuanxing, a famous Chinese questionnaire survey platform to gain the data for exploratory factor analysis. The age of participants has been limited in 45-60, 344 responses have been collected. To be more specific, 178(51.7%) participants were male and 166(48.3%) were men. With regard to the ages, 128(37.2%) were between the age of 45 and 50, 125(36.3%) were between the age of 51 and 55, 91(26.5%) were between the age of 56 and 60. The education level, marital status, income and occupation information also have been clarified, which can be seen in Table 4.

Table 4. Demographic information for exploratory factor analysis

Attribute	Value	Freq.	%	Attribute	Value	Freq.	%
Gender	Male	178	51.7		<1000	33	9.6
	Female	166	48.3	Monthly	1000-3000	88	25.6
Age	45-50	128	37.2	Income	3000-5000	91	26.5
	51-55	125	36.3	(RMB)	5000-7000	86	25.0
	56-60	91	26.5		7000-10000	21	6.1
Education	<High school	131	38.0		10000+	25	7.3
	High school	44	12.8	Occupation	Teacher	19	5.5
	Associate	63	18.3		Civil Servant	17	4.9
	Bachelor	64	18.6		IT company staff	16	4.7
	Master	31	9.0		Non-IT company staff	108	31.4
	Doctor	11	3.2		Private entrepreneur	19	5.5
Marital	Single	50	14.5		Freelancer	21	6.1
status	Married	254	73.8		Worker	86	25.0
	Divorced	22	6.4		Farmer	22	6.4
	Widowed	28	5.2		Others	36	10.4

5.5.1.2 Exploratory factor analysis of perceived risk

A principal axis factoring analysis with varimax orthogonal rotation was conducted. For the exploratory factor analysis of perceived risk scale, the results showed the Kaiser-Meyer-Olkin(KMO) measure of sampling was 0.914 and Bartlett's test(Chi-square) value was 17620.868 (p=0.000), suggesting that it is suitable for factor analysis [47]. Each construct was examined and determined in terms of eigenvalues and the scree plot. In terms of item selection for the ten factors, all the items were appealed to the condition that singly loading onto one factor with coefficients greater than 0.50 [48]. Factor loadings with varimax rotation were provided in Table 5.

Table 5. Varimax rotation method for the perceived risk scale in ten factors

Items	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7	Factor 8	Factor 9	Factor 10
SS8	.834	.017	.045	.040	-.001	.022	.017	.061	.016	.081
SS2	.817	.071	.073	.057	.006	.059	-.015	.093	.134	.066
SS7	.792	.065	.021	.079	.065	.049	.044	.112	.163	-.022
SS5	.792	.021	.052	-.008	.020	.097	.009	.094	.014	.065
SS9	.792	.004	.135	.036	.002	.048	.028	.038	.112	-.032
SS10	.790	.003	.093	-.054	.025	.047	.059	.122	.088	.050
SS1	.784	.044	.117	.015	-.068	-.021	-.005	.076	.021	-.002
SS3	.783	-.069	.016	.056	-.015	.089	.085	.137	.106	.017
SS4	.775	.001	.083	.011	.053	.021	.062	.115	.093	-.043
SS6	.771	.034	.076	.045	.033	-.005	-.058	.129	.167	.033
SER6	.024	.812	.069	.144	.037	.029	-.032	.088	.096	.053
SER9	.031	.798	.069	.183	.012	.005	.124	.098	.048	.025
SER2	.031	.791	.090	.154	.049	.019	.096	-.019	.039	-.003
SER5	-.037	.791	.033	.116	.029	-.004	.044	.056	.059	.113
SER8	.037	.789	.117	.177	.017	.027	.025	.025	.050	.008
SER1	.078	.778	.100	.200	-.038	.070	-.003	.027	-.046	.048
SER7	.045	.772	.036	.186	.097	.007	.071	.066	.025	.030
SER4	-.029	.768	.122	.184	-.002	-.038	.069	.037	.001	.050
SER3	.009	.748	.090	.158	-.020	-.032	.000	.030	.051	.129
TECH10	.103	.089	.780	.066	.047	-.005	.085	.046	.011	.097
TECH7	.037	.052	.768	.120	.125	.000	.026	.138	.035	-.013
TECH6	.038	.053	.750	.206	.040	.045	.055	.067	.038	-.044
TECH2	.108	.084	.749	.042	.073	.016	.028	.107	.058	.021
TECH4	.060	.104	.733	.204	.049	.025	.071	.113	.081	.072
TECH8	.057	.130	.729	.132	.073	.000	.061	.133	-.028	-.002
TECH1	.080	.065	.718	.188	.064	-.068	-.017	.149	.017	.084
TECH9	.086	.010	.717	.268	.103	.033	.029	.094	-.023	-.046
TECH3	.057	.084	.716	.133	.092	.087	.040	.099	.007	-.065
TECH5	.114	.079	.694	.114	-.024	.038	-.009	.173	.091	.070
PER6	-.010	.182	.135	.782	.034	-.018	-.049	.145	.050	-.049
PER8	.064	.235	.207	.771	.025	-.070	.082	.001	.066	.030
PER3	.077	.175	.170	.752	.027	.061	.031	.052	.054	.078
PER4	.057	.254	.174	.748	-.002	.019	.024	.057	.117	.001
PER7	-.051	.213	.263	.737	.028	.055	.060	.063	.085	-.013
PER1	.084	.211	.221	.719	.037	.112	.045	.073	.111	.005
PER5	.067	.229	.186	.717	.000	.134	.029	.059	.097	.092
PER2	-.009	.288	.260	.678	.081	-.001	.050	.024	-.012	.121
PHY2	-.023	.029	.039	.029	.767	.162	.083	.051	-.060	.159
PHY1	-.022	-.023	.093	.010	.764	.176	.003	.063	-.011	.073
PHY7	.033	-.050	.149	.003	.751	.157	-.055	.118	.031	.076
PHY6	-.044	.103	.047	-.046	.747	.208	.107	.025	.025	.052
PHY8	.037	.029	.053	.081	.741	.117	.125	-.010	.046	-.015
PHY4	.002	-.021	.005	.023	.716	.236	.060	.028	-.021	.109

PHY3	.069	.039	.074	.037	.708	.217	.015	.021	.037	.132
PHY5	.042	.086	.183	.063	.679	.275	.009	.005	-.004	.114
PSY3	.045	.010	.031	.050	.211	.809	.085	.007	-.012	.141
PSY4	.053	.059	.044	.050	.192	.786	.118	.038	-.034	.154
PSY6	.038	-.030	.034	.026	.196	.785	.114	.015	.005	.163
PSY7	.061	.000	-.069	.007	.293	.758	.060	.038	.068	.118
PSY1	.046	-.001	.029	.047	.294	.756	.118	.094	.059	.142
PSY5	.103	.000	-.006	.086	.243	.748	.170	.004	.073	.128
PSY2	.079	.025	.086	.000	.279	.745	.037	.002	.090	.101
PL5	.046	.061	.030	.050	.164	.090	.828	.008	.024	.130
PL6	.018	.082	.081	.032	.069	.108	.828	.002	.049	.091
PL4	.035	.062	.026	.040	-.001	.088	.819	.074	.059	.144
PL3	.067	.038	.001	.009	.049	.069	.807	.112	.016	.173
PL1	-.010	.054	.111	.052	.044	.104	.800	.086	.040	.137
PL2	.048	.058	.086	.026	.017	.150	.798	.121	.032	.154
PS3	.146	.048	.116	.108	.111	-.005	.059	.770	-.063	.017
PS4	.059	.032	.102	.095	.075	.001	.058	.766	-.026	.073
PS1	.143	.001	.148	.030	.067	.055	.035	.762	-.054	.034
PS5	.145	.052	.155	.073	-.018	.096	.020	.759	-.024	-.013
PS7	.137	.001	.190	.044	.018	-.008	.080	.756	-.034	.046
PS6	.154	.094	.173	.021	.014	.019	.065	.747	.060	.043
PS2	.148	.157	.137	.032	.018	.015	.088	.715	.003	.049
IM2	.120	.073	.076	-.004	-.003	-.025	.053	-.068	.827	.047
IM3	.134	.076	.035	.051	.012	-.006	.032	-.045	.822	-.003
IM1	.161	.062	.054	.081	.012	.043	.042	.014	.811	.084
IM5	.107	.085	.042	.088	.012	.086	.051	.011	.807	-.010
IM6	.161	.031	.030	.122	.002	.050	.019	-.011	.802	.020
IM4	.123	-.035	.008	.110	.012	.046	.018	-.036	.784	.051
FIN3	.089	.048	-.001	.087	.123	.194	.168	.021	.038	.797
FIN4	-.018	.072	.013	.050	.145	.131	.232	.085	.054	.769
FIN5	.033	.108	.048	.056	.126	.199	.265	.052	.035	.757
FIN2	.060	.148	.041	-.009	.177	.241	.172	.103	.079	.752
FIN1	.046	.116	.057	.028	.184	.226	.145	.021	.018	.744

Notes: Rotation method: Varimax. Extraction method: Principal axis factoring. Rotation converged in seven iterations with loading values of more than 0.5.

5.5.2 Confirmatory factor analysis

Based on the result of the exploratory factor analysis, confirmatory factor analysis (CFA) was used to evaluate the perceived risk scale which including 75 items.

5.5.2.1 Respondents

The similar data collection method with exploratory factor analysis was applied. The online questionnaire survey through Wenjuanxing was conducted with the age limitation between 45 to 60 for the participants. 590 responses have been collected. To be more specific,321(54.5%) participants were male and 269(45.6%) were female. With regard to the ages, 234(39.7%) were between the age of 45 and 50, 210(35.6%) were between the age of 51 and 55, 146(24.7%) were between the age of 56 and 60. The education level, marital status, income and occupation information also have been clarified, which can be seen in Table 6.

Table 6. Demographic information for confirmatory factor analysis

Attribute	Value	Freq.	%	Attribute	Value	Freq.	%
Gender	Male	321	54.4	Monthly	<1000	59	10.0
	Female	269	45.6	Income	1000-3000	25.6	25.6
Age	45-50	234	39.7	(RMB)	3000-5000	26.8	26.8
	51-55	210	35.6		5000-7000	25.1	25.1
	56-60	146	24.7		7000-10000	5.6	5.6
Education	<High school	219	37.5		10000+	6.9	6.9
	High school	84	14.2	Occupation	Teacher	28	4.7
	Associate	109	18.5		Civil Servant	31	5.3
	Bachelor	108	18.3		IT company staff	32	5.4
	Master	51	8.6		Non-IT company staff	182	30.8
	Doctor	17	2.9		Private entrepreneur	31	5.3
Marital	Single	92	15.6		Freelancer	30	5.1
status	Married	434	73.6		Worker	162	27.4
	Divorced	41	6.9		Farmer	34	5.8
	Widowed	23	3.9		Others	60	10.1

5.5.2.2 Confirmatory factor analysis of perceived risk

The results showed that the original model did not provide an adequate model fit (X^2=2777.023; p=0.000; SRMR=0.027; RMSEA=0.005; CFI=0.998; NFI=0.902; IFI=0.998; TLI=0.998; GFI=0.894). Following the suggestions from Woosnam and Norman, reasonable modifications were introduced based on the correlated residuals and cross-loadings, producing a good model fit [49]. Regarding this, the first modified model contained 73 items, producing a better model fit for the data (X^2=2547.373; p=0.000; SRMR=0.027; RMSEA=0.005; CFI=0.999; NFI=0.905; IFI=0.999; TLI=0.999; GFI=0.898). However, the vital index NFI and GFI still can not reach the threshold so that the second modification was conducted. The second modified model contained 70 items based on the first revision, which indicates that all the model fit indices thresholds have been reached (X^2=2326.904; p=0.000; SRMR=0.026; RMSEA=0.004; CFI=0.999; NFI=0.908; IFI=0.999; TLI=0.999; GFI=0.903). Table 7 presents the model fit indices for the original and revised models. Figure 5.1 shows the path diagram of the second model modification of the perceived risk scale of smart home for future elderly.

Table 7. Model fit for perceived risk scale

Models	X^2	d.f.	X^2/d.f.	SRMR	RMSEA	CFI	NFI	IFI	TLI	GFI
Item 75	2777.023	2732	1.016	0.027	0.005	0.952	0.902	0.952	0.949	0.894
Item 73	2547.373	2513	1.014	0.027	0.005	0.956	0.905	0.957	0.953	0.898
Item 70	2326.904	2303	1.010	0.026	0.004	0.961	0.908	0.962	0.957	0.903
Threshold			1-5	0.08	0.08	0.90	0.90	0.90	0.90	0.90

Note: SRMR represents standardized root mean square residual; RMSEA represents root mean square error of approximation; CFI represents the comparative fit index; NFI represents normal fit index; IFI represents the incremental fit index; TLI represents Tucker-Lewis Index; GFI represents the goodness of fit.

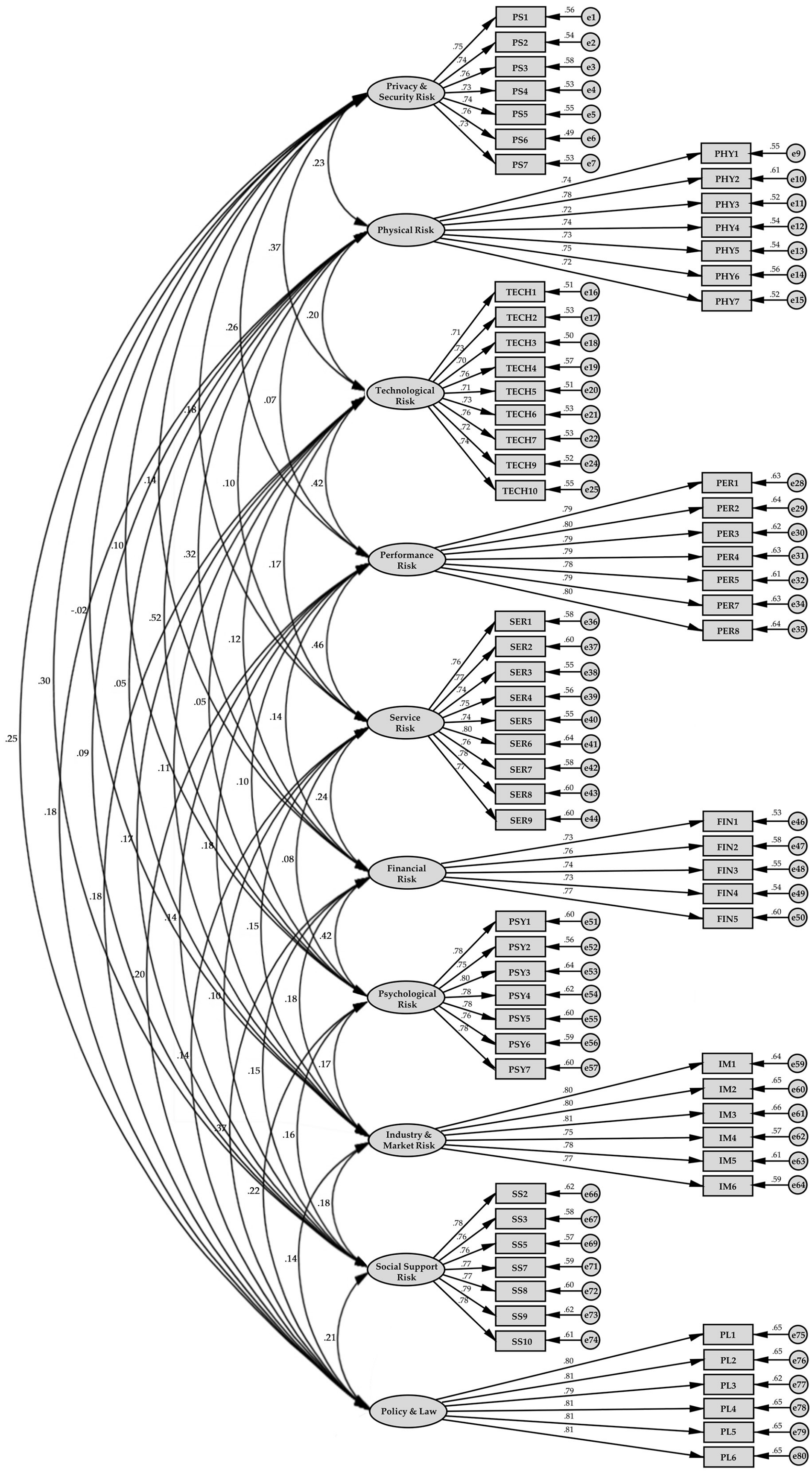

Figure 5.2. The path diagram of the perceived risk scale

5.5.3 Convergent and discriminant validity

Confirmatory factory analysis was conducted to determine the convergent and discriminant validity of the perceived risk scale. For convergent validity, the standardized factor loadings should be above the threshold, 0.5 or above, C.R. (t-value) should be above the threshold, 2 or above, and the averaged variances expected (AVE) value should also be above the threshold, 0.5 or above [50]. Table 8 shows that the C.R. (t-value), standardized factor loadings, and AVE achieved adequate values.

Table 8. Convergent and discriminant validity of the perceived risk scale.

Construct	Cronbach's Alpha	Variable	Mean	Standard Deviation	Standardized Factor Loading	C.R. (t-Value)	SMC	AVE	Composite Reliability
Privacy &Security Risk	0.892	PS1	3.97	0.777	0.745	-	0.555	0.540	0.891
		PS2	3.96	0.797	0.725	17.592	0.541		
		PS3	3.94	0.799	0.761	18.222	0.579		
		PS4	3.97	0.811	0.731	17.509	0.534		
		PS5	3.96	0.799	0.740	17.892	0.548		
		PS6	3.95	0.790	0.703	16.798	0.494		
		PS7	3.98	0.784	0.727	17.483	0.529		
Physical Risk	0.896	PHY1	3.88	0.949	0.742	-	0.551	0.548	0.894
		PHY2	3.86	0.971	0.779	18.908	0.607		
		PHY3	3.84	0.917	0.718	17.215	0.516		
		PHY4	3.92	0.880	0.738	17.714	0.545		
		PHY5	3.86	0.950	0.733	17.510	0.537		
		PHY6	3.87	0.957	0.749	18.038	0.561		
		PHY7	3.88	0.921	0.720	17.315	0.518		
Technological Risk	0.912	TECH1	3.32	0.845	0.712	-	0.507	0.531	0.911
		TECH2	3.31	0.873	0.725	16.982	0.525		
		TECH3	3.34	0.828	0.704	16.457	0.495		
		TECH4	3.34	0.849	0.756	17.013	0.572		
		TECH5	3.34	0.860	0.714	16.592	0.510		
		TECH6	3.34	0.896	0.729	16.985	0.531		
		TECH7	3.34	0.870	0.758	17.656	0.575		
		TECH9	3.27	0.857	0.721	16.905	0.519		
		TECH10	3.30	0.851	0.739	17.256	0.547		
Performance Risk	0.928	PER1	3.93	0.878	0.791	-	0.625	0.627	0.922
		PER2	3.88	0.883	0.797	20.957	0.635		
		PER3	3.88	0.890	0.786	20.674	0.617		
		PER4	3.89	0.870	0.795	20.916	0.632		
		PER5	3.87	0.897	0.782	20.535	0.612		
		PER6	3.93	0.855	0.793	20.951	0.629		
		PER7	3.90	0.909	0.799	21.060	0.638		
	0.926	SER1	3.97	0.863	0.762	-	0.581	0.583	0.926
		SER2	3.98	0.838	0.773	19.523	0.598		

Service Risk		SER3	4.00	0.848	0.738	18.499	0.545		
		SER4	3.88	0.883	0.750	18.837	0.563		
		SER5	4.00	0.823	0.741	18.507	0.549		
		SER6	3.96	0.869	0.798	20.293	0.637		
		SER7	3.98	0.823	0.760	19.107	0.577		
		SER8	4.00	0.864	0.777	19.586	0.603		
		SER9	3.98	0.860	0.773	19.473	0.598		
Financial Risk	0.861	FIN1	3.63	0.855	0.725	-	0.526	0.558	0.863
		FIN2	3.72	0.782	0.762	17.009	0.581		
		FIN3	3.66	0.824	0.739	16.544	0.546		
		FIN4	3.62	0.816	0.734	16.476	0.539		
		FIN5	3.65	0.797	0.773	17.170	0.598		
Psychological Risk	0.913	PSY1	3.73	0.866	0.776	-	0.601	0.601	0.913
		PSY2	3.76	0.847	0.746	19.067	0.556		
		PSY3	3.77	0.874	0.801	20.593	0.641		
		PSY4	3.76	0.864	0.785	20.013	0.616		
		PSY5	3.76	0.835	0.775	19.852	0.601		
		PSY6	3.80	0.841	0.765	19.529	0.585		
		PSY7	3.72	0.888	0.777	19.887	0.603		
Industry & Market Risk	0.908	IM1	3.03	0.988	0.797	-	0.636	0.617	0.906
		IM2	3.08	0.954	0.804	21.505	0.647		
		IM3	3.03	0.961	0.810	21.753	0.656		
		IM4	3.16	0.964	0.753	19.781	0.567		
		IM5	3.00	0.950	0.783	20.798	0.613		
		IM6	3.04	0.951	0.766	20.041	0.586		
Social Support Risk	0.912	SS2	3.50	0.919	0.785	-	0.616	0.598	0.912
		SS3	3.51	0.862	0.764	19.797	0.583		
		SS4	3.49	0.860	0.755	19.494	0.570		
		SS5	3.51	0.870	0.770	20.021	0.593		
		SS8	3.48	0.895	0.773	20.124	0.597		
		SS9	3.53	0.898	0.786	20.588	0.618		
		SS10	3.51	0.897	0.780	20.221	0.609		
Policy & Law Risk	0.912	PL1	3.58	1.035	0.805	-	0.648	0.645	0.916
		PL2	3.57	1.021	0.807	21.645	0.651		
		PL3	3.56	1.066	0.788	20.864	0.620		
		PL4	3.57	1.026	0.806	21.648	0.650		
		PL5	3.57	1.028	0.809	21.833	0.654		
		PL6	3.54	0.991	0.805	21.499	0.649		

The correlation coefficients, the maximum shared variance (MSV) and average shared variance (ASV) tend to be used to assess discriminant validity. To specify, the threshold for MSV and ASV values should be less than the AVE value [50]. The results of Table 9 show that, in the current study, all the AVE values are above the MSV and ASV values, suggesting that the four constructs achieved satisfactory discriminant validity.

Table 9. Correlation and discriminant validity of the perceived risk scale.

Construct	CR	AVE	MSV	ASV	PS	PHY	TECH	PER	SER	FIN	PSY	IM	SS	PL
PS	0.891	0.540	0.137	0.052	0.735									
PHY	0.894	0.548	0.266	0.058	0.226***	0.740								
TECH	0.911	0.531	0.180	0.053	0.370***	0.204***	0.729							
PER	0.922	0.627	0.211	0.065	0.256***	0.065***	0.424***	0.804						
SER	0.926	0.583	0.211	0.044	0.179***	0.103***	0.170***	0.459***	0.764					
FIN	0.863	0.558	0.175	0.065	0.141***	0.323***	0.116***	0.141***	0.239***	0.747				
PSY	0.913	0.601	0.266	0.063	0.099***	0.516***	0.052***	0.096***	0.084***	0.418***	0.775			
IM	0.906	0.617	0.034	0.020	-0.017***	0.050***	0.108***	0.180***	0.153***	0.180***	0.167***	0.785		
SS	0.912	0.598	0.091	0.032	0.301***	0.092***	0.171***	0.143***	0.102***	0.147***	0.162***	0.185***	0.773	
PL	0.916	0.645	0.139	0.048	0.255***	0.185***	0.175***	0.196***	0.138***	0.373***	0.217***	0.136***	0.206***	0.803

Note: PS represents Privacy & Security Risk; PHY represents Physical Risk; TECH represents Technological Risk; PER represents Performance Risk; SER represents Service Risk; FIN represents Financial Risk; PSY represent Psychological Risk; IM represents Industry & Market Risk; SS represents Social Support Risk; PL represents Policy & Law Risk; *** $p < 0.01$.

5.6 Conclusion and discussion

In this chapter, the author conducted a scale development and validity study on the perceived risk of smart homes for the elderly. From the questionnaire survey and data analysis results, the variables and corresponding measurement items proposed in this study have been verified. In the upcoming future, smart homes will have huge potential in helping the elderly aging in place and dealing with aging population challenges. However, there are still numerous problems that need to be resolved. These problems will cause varying degrees of risks to the usage of smart homes for the elderly. In order to conduct a comprehensive assessment of the possible risks of smart homes from customer-oriented perspective, this chapter takes future elderly people aged 45-60 in China as the research object. Through literature analysis, user interviews and expert interviews, the perceived risk dimensions and relevant measurement items of smart homes for the elderly are generated. Through pre-study, exploratory factor analysis, confirmatory factor analysis, the reliability and validity of each dimension and its corresponding observation variables, a perceived risk scale of smart homes for the elderly has been developed and verified. The scale includes ten factors and seventy measurement items. Among them, there are 7 items for Privacy & Security Risk (PS), 7 for Physical Risk (PHY), 9 for Technological Risk (TECH), 7 for Performance Risk (PER), 9 for Service Risk (SER), 5 for Financial Risk (FIN), 7 for Psychological Risk (PSY), 6 for Industry & Market Risk (IM), and 7 for Social Support Risk (SS). 6 for Policy & law risk (PL). This scale is the first systematic risk assessment scale taking smart homes for the elderly as the research object which is of milestone significance. It helps the industry, enterprises, manufacturers identify the risks and obstacles of smart homes services and products for the elderly from the user-centered perspective, so that the relevant risks could be controlled, reduced or avoided as much as possible. Through this way, the development of smart homes industry for the elderly could be promoted and the users adoption and acceptance of relevant products and services could be improved. Each risk factors is discussed in detail as follows:

- **Privacy & Security Risk:** For "Privacy & Security Risk", the final observed variables include seven items, they are PS1, PS2, PS3, PS4, PS5, PS6, and PS7, their factor loadings are 0.745, 0.725, 0.761, 0.731, 0.740, 0.703, and 0.727 which are all higher than 0.5. The Cronbach's α of these seven measurements is 0.892>0.7, the AVE is 0.540>0.5, the Composite Reliability is 0.891>0.7. The related key indexes all present adequate value which reveals that the seven items of the "Privacy & Security Risk" dimension achieve satisfactory reliability and validity. On one hand, the elderly do not like the sense of surveillance brought by smart homes to share their personal lives and privacy with others, even their family members. For example, some seniors may do not want to share their sensitive health information with their important persons, like couple or children, to increase unnecessary worries; On the other hand, for platforms, service providers, work staffs, and related stakeholders of elderly service enterprises, " What kind of extent should the data and personal information be opened to them to support the implementation of related system functions and services as well as avoiding the sense of privacy invasion" is a topic worth significant concerns. Moreover, the elderly will also worry about their personal information and privacy data will be expose to unauthorized third-party without permission, or be stolen by hackers for illegal purposes, etc. Thus, smart homes for the elderly should emphasize on the protection of the elderly privacy and security, give them sufficient autonomy and control over their personal information and data, and try to find a balance between the privacy protection and high-quality services provision.

- **Physical Risk:** For "Physical Risk", the final observed variables include seven items, they are PHY1, PHY2, PHY3, PHY4, PHY5, PHY6, and PHY7, their factor loadings are 0.742, 0.779, 0.718, 0.738, 0.733, 0.749, and 0.720 which are all higher than 0.5. The Cronbach's α of these seven measurements is 0.896>0.7, the AVE is 0.548>0.5, the Composite Reliability is 0.894>0.7. The related key indexes all present adequate value which reveals that the seven items of the "Physical Risk" dimension achieve satisfactory reliability and validity. Since the personal information and daily life data of the elderly could been collected by the sensor systems while using smart homes, there may be some hidden risk of fraud, theft, robbery, blackmail and extortion because of the information leakage. In addition, with the increase of age, the physical ability of the elderly will go through a obvious decline. Thus, the physical materials of the smart home devices or equipment may bring physical harm to the elderly if they are sharp, or hard, or the surface friction is too small. For example, the small friction of the bathroom floor may lead to a fall for the elderly. Moreover, some accidental injuries may occur due to the execution of wrong commands, and incorrect or untimely feedback from the system. Last but not least, the electromagnetic radiation from the smart system may also bring some potential health problems. Therefore, the data security should receive specific attention during the usage process. At the same time, the material and physical form of smart home devices should also cater to the physical and psychological characteristics of the elderly, such as rounded corners, anti-skid treatment, etc. The system reliability should be optimized, so as to ensure the accuracy of information delivery and command transmission, timely responsiveness should also be guaranteed. Finally, related technologies should be rigorously tested before being applied in a large number of applications to avoid potential health harms to the elderly.
- **Technological Risk:** For "Technological Risk", the final observed variables include nine items, they are TECH1, TECH2, TECH3, TECH4, TECH5, TECH6, TECH7, TECH9, and TECH10, their factor loadings are 0.712, 0.725, 0.704, 0.756, 0.714, 0.729, 0.758, 0.721, and 0.739 which are all higher than 0.5. The Cronbach's α of these nine measurements is 0.912>0.7, the AVE is 0.531>0.5, the Composite Reliability is 0.911>0.7. The related key indexes all present adequate value which reveals that the nine items of the "Technological Risk" dimension achieve satisfactory reliability and validity. They mainly include low accuracy of the command identification, malfunction, system failures, error alarms, instability, low expansion capability, lack of interoperability among different devices and heterogeneous systems, inflexibility, low intelligence, inability to customize services for users, insufficient data processing and management capabilities (collection record, storage, treatment, compression, delivery). For smart homes system, technology is the development basis of relevant intelligent products and services which deserves long-term emphasis. The advancement of technology can solve a bunch of existing problems, such as improving the accuracy of command identification and execution, reducing system failures and errors, improving compatibility between different products and operating systems, etc. Individual customized services, smart recommendations, active behavioral responses, etc., could also been realized via deep learning and data training of a large amount of user behaviors' data.

- **Performance Risk:** For "Performance Risk", the final observed variables include seven items, they are PER1, PER2, PER3, PER4, PER5, PER6, and PER7, their factor loadings are 0.791, 0.797, 0.786, 0.795, 0.782, 0.793, and 0.799 which are all higher than 0.5. The Cronbach's α of these seven measurements is 0.928>0.7, the AVE is 0.627>0.5, the Composite Reliability is 0.922>0.7. The related key indexes all present adequate value which reveals that the seven items of the "Performance Risk" dimension achieve satisfactory reliability and validity. The current smart home development attaches great importance to "intelligence" and "high-tech" which are mostly aimed at young group, and there is a lack of concerns on catering to the physical, psychological and cognitive demands of the elderly from a user-centered perspective. In addition, it does not fully consider the operating customs of the elderly and ignores their characteristics, which makes it difficult for the elderly to operate and cause low accessibility. Therefore, the design and development of related products and services should take the core demands of the elderly as the start points and improve the usability and ease of use according to the elders' features. Moreover, a plenty of smart home devices are aesthetic incongruence which cannot integrate with house environment of the elderly, some of them are obstruction or impediment in space and make the seniors feel uncomfortable at home. Thus, the hardware and software design of the smart home products should take these issues into consideration. Last but not least, some smart home products not only cannot bring comfort and convenience to the elderly, but also affect and disrupt their normal life routines. In view of these, designers and developers should start from the functions, appearance, materials, operation, software of related products and services, and consider the characteristics of the elderly from a comprehensive perspective to minimize the corresponding risk and optimize user experience.
- **Service Risk:** For "Service Risk", the final observed variables include nine items, they are SER1, SER2, SER3, SER4, SER5, SER6, SER7, SER8, and SER9, their factor loadings are 0.762, 0.773, 0.738, 0.750, 0.741, 0.798, 0.760, 0.777, and 0.773 which are all higher than 0.5. The Cronbach's α of these nine measurements is 0.926>0.7, the AVE is 0.583>0.5, the Composite Reliability is 0.926>0.7. The related key indexes all present adequate value which reveals that the nine items of the "Service Risk" dimension achieve satisfactory reliability and validity. They are unreliability, no timely response, lack of service guarantee, inconsistent business promise from the service providers, incompetent service staffs, and inability to provide customized services according to different individual needs. As we can see, the service risk resources are not only from the non-human factors such as the system stability, but also from the service deliverers. If the service deliverer is in bad manner, low neatness and cleanness, unable to understand the elders' specific needs and lack of empathy, there is no possibility that the service quality will present a high level. In response to these issues, smart home services for the elderly should integrate the special physical and psychological needs of the elderly, and comprehensively improve the reliability, responsiveness, security, and professionalism from the human and non-human aspects to deliver high-quality services for the elderly.
- **Financial Risk:** For "Financial Risk", the final observed variables include 5 items. the final observed variables include five items, they are FIN1, FIN2, FIN3, FIN4, and FIN5, their factor loadings are 0.725, 0.762, 0.739, 0.734, and 0.773 which are all higher than 0.5. The Cronbach's α of these five measurements is 0.861>0.7, the AVE is 0.558>0.5, the Composite

Reliability is 0.863>0.7. The related key indexes all present adequate value which reveals that the five items of the "Financial Risk" dimension achieve satisfactory reliability and validity. It is mainly reflected in that the purchase of related smart home products and services exceeds the elders' affordability, or makes them feel that the value benefits they get are not worth the high prices, or the use of some products and services requires continuous payment, or there are unnecessary expenses for them, and may bring them financial pressure. Based on these problems, the design and development of smart home products and services for the elderly should try to reduce development and production costs as much as possible to make the majority of aging group can afford as well as providing the elderly with value beyond their expectations. At the same time, we should also consider to maximize the use of the existing or easy-acquired resources of the elderly to reduce their financial expenditure, such as selling sensor and controllers to make the non-smart products in home environment become intelligent, using the existing smart devices (phone, pad, laptop, TV, etc.) as the service carriers instead of develop new media and products, etc.

- **Psychological Risk:** For "Psychological Risk", the final observed variables include seven items, they are PSY1, PSY2, PSY3, PSY4, PSY5, PSY6, and PSY7, their factor loadings are 0.776, 0.746, 0.801, 0.785, 0.775, 0.765, and 0.777 which are all higher than 0.5. The Cronbach's α of these seven measurements is 0.913>0.7, the AVE is 0.601>0.5, the Composite Reliability is 0.913>0.7. The related key indexes all present adequate value which reveals that the seven items of the "Psychological Risk" dimension achieve satisfactory reliability and validity. Older people are more sensitive than youth in psychological aspect. When using smart home products and services, they will worry about family members' blame, care about friends' opinions, and will also consider burdening co-living people, etc. At the same time, the elderly is also afraid of being treated as old and vulnerable. For example, some products have strong psychological hints of aging in appearance, which will actually make the elderly feel disappointed all the time and hurt their self-esteem. On one hand, the powerful functions of smart products will give people a sense of spiritual oppression. This kind of oppression is even more serious for older adults compared to young group and will make them psychologically produce pessimistic and negative resistance; on the other hand, powerful functions may also cause the elderly over-reliance on intelligent technology which may passively reduce their interpersonal communication and causes social isolation. These issues need to be taken seriously during the design, development, and delivery process of smart home products and services for the elderly.

- **Industry & Market Risk:** For "Industry & Market Risk", the final observed variables include six items, they are IM1, IM2, IM3, IM4, IM5, and IM6, their factor loadings are 0.797, 0.804, 0.810, 0.753, 0.783, and 0.766 which are all higher than 0.5. The Cronbach's α of these six measurements is 0.908>0.7, the AVE is 0.617>0.5, the Composite Reliability is 0.906>0.7. The related key indexes all present adequate value which reveals that the six items of the "Industry & Market Risk" dimension achieve satisfactory reliability and validity. It is mainly reflected in the smart homes for the elderly currently lacks a comprehensive market environment, the existing smart products and services for the elderly are incomplete, there is no consistency industry standardization and regulation so that the compatibility between products and systems of different brands is poor, the service quality lacks a unified qualification standard certification, there is a shortage of service personnel in the relevant elderly care service industry. These problems all reflect the immaturity of the smart home market for the elderly. In response to these problems, it is necessary to set up an industry organization to propose unified standards and rules for products, services, technologies and talent qualification certification in related industries, improve product and system compatibility of different brands, and promote the construction of an overall service team in the industry.

- **Social Support Risk:** For "Social Support Risk", he final observed variables include seven items, they are SS2, SS3, SS4, SS5, SS8, SS9, and SS10, their factor loadings are 0.813, 0.727, 0.784,0.739, 0.784,0.739, and 0.755 which are all higher than 0.5. The Cronbach's α of these seven measurements is 0.912>0.7, the AVE is 0.598>0.5, the Composite Reliability is 0.912>0.7. The related key indexes all present adequate value which reveals that the seven items of the "Social Support Risk" dimension achieve satisfactory reliability and validity. It refers to the implementation of some products and system functions of smart homes need to be supported by relevant social forces, such as family members (children and partners), relatives, neighbors, communities, social organizations and institutions, as well as related service personnel groups, such as nurses, clinical staff, medical experts, etc. The lack of these support or the lack of relevant service personnel will create risks and bring obstacles to the realization of the relevant functions of the smart home system for the elderly. Therefore, a smart home system with a full sense of happiness for the elderly need the support of a strong social network which make the construction of social support network is of great importance and crucial significance.
- **Policy & Law Risk:** For "Policy & Law Risk", the final observed variables include six items, they are PL1, PL2, PL3, PL4, PL5, and PL6, their factor loadings are 0.805, 0.807, 0.788, 0.806, 0.809, and 0.805 which are all higher than 0.5. The Cronbach's α of these six measurements is 0.912>0.7, the AVE is 0.645>0.5, the Composite Reliability is 0.916>0.7. The related key indexes all present adequate value which reveals that the six items of the "Policy & Law Risk" dimension achieve satisfactory reliability and validity. It refers to the government or relevant authorities that have not promulgated and issued relevant policies and laws to regulate the development of the smart home industry, improve service quality, and provide legal guarantees for the consumers right. It mainly includes the lack of policy and law formulation, implementation, interpretation, and supervision, and when the consumers' rights are violated due to the negligence, defects, and non-professionalism of the smart home system and its service providers, there is no relevant law to provide guarantee and assistance. Therefore, in order to guide and regulate the market, improve the service level of service personnel, and provide consumers with the assurance of rights and interests, the formulation, promulgation and implementation of government policies and related laws are urgent and necessary.

Reference

1. Churchill Jr, G.A. A paradigm for developing better measures of marketing constructs. *Journal of marketing research* **1979**, *16*, 64-73.
2. DeVellis, R.F. *Scale development: Theory and applications*; Sage publications: 2016; Volume 26.
3. Gerbing, D.W.; Anderson, J.C. An updated paradigm for scale development incorporating unidimensionality and its assessment. *Journal of marketing research* **1988**, *25*, 186-192.
4. Mitchell, V.W. Consumer perceived risk: conceptualisations and models. *European Journal of marketing* **1999**.
5. Bauer, R.A. Consumer behavior as risk taking. In Proceedings of the Proceedings of the 43rd National Conference of the American Marketing Assocation, June 15, 16, 17, Chicago, Illinois, 1960, 1960.
6. Smith, D.; Riethmuller, P. Consumer concerns about food safety in Australia and Japan. *International Journal of Social Economics* **1999**.
7. Cox, D.F. Risk taking and information handling in consumer behavior. **1967**.
8. Featherman, M.S.; Pavlou, P.A. Predicting e-services adoption: a perceived risk facets perspective. *International journal of human-computer studies* **2003**, *59*, 451-474.
9. Jacoby, J.; Kaplan, L.B. The components of perceived risk. *ACR special volumes* **1972**.
10. Mitchell, V.W.; Harris, G. The importance of consumers' perceived risk in retail strategy. *European Journal of marketing* **2005**.
11. Cunningham, L.F.; Gerlach, J.H.; Harper, M.D.; Young, C.E. Perceived risk and the consumer buying process: internet airline reservations. *International Journal of Service Industry Management* **2005**.
12. Tse, A.C.B. Factors affecting consumer perceptions on product safety. *European journal of marketing* **1999**.
13. Kudzai, M.; Cilliers, L. Mitigating the elderly's privacy concerns when making use of Mobile Monitoring and Care systems. In Proceedings of the 2016 IST-Africa Conference, IST-Africa 2016, 2016.
14. Zhang, Q.; Li, M.Y.; Wu, Y.J. Smart home for elderly care: development and challenges in China. *Bmc Geriatrics* **2020**, *20*, doi:10.1186/s12877-020-01737-y.
15. Peek, S.T.M.; Aarts, S.; Wouters, E.J.M. Can smart home technology deliver on the promise of independent living? A critical reflection based on the perspectives of older adults. In *Handbook of Smart Homes, Health Care and Well-Being*; 2016; pp. 203-214.
16. Dewsbury, G.; Clarke, K.; Rouncefield, M.; Sommerville, I.; Taylor, B.; Edge, M. Designing acceptable 'smart' home technology to support people in the home. *Technology and Disability* **2003**, *15*, 191-199, doi:10.3233/tad-2003-15305.
17. Maeder, A.J.; Williams, P.A.H. Health smart homes: New challenges. *Studies in Health Technology and Informatics* **2017**, *245*, 166-169, doi:10.3233/978-1-61499-830-3-166.
18. Taiwo, O.; Gabralla, L.A.; Ezugwu, A.E. Smart Home Automation: Taxonomy, Composition, Challenges and Future Direction. *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)* **2020**, *12254 LNCS*, 878-894, doi:10.1007/978-3-030-58817-5_62.
19. Lê, Q.; Nguyen, H.B.; Barnett, T. Smart Homes for Older People: Positive Aging in a Digital World. *Future Internet* **2012**, *4*, 607-617, doi:10.3390/fi4020607.

20. Wilkowska, W.; Ziefle, M. User diversity as a challenge for the integration of medical technology into future smart home environments. In *User-Driven Healthcare: Concepts, Methodologies, Tools, and Applications*; 2013; Volume 2, pp. 553-582.
21. Ghorayeb, A.; Comber, R.; Gooberman-Hill, R. Older adults' perspectives of smart home technology: Are we developing the technology that older people want? *International Journal of Human Computer Studies* **2021**, *147*, doi:10.1016/j.ijhcs.2020.102571.
22. Satpathy, L.; Mathew, A.P. 'Smart' housing for the elderly: Understanding perceptions and biases of rural America. In Proceedings of the Expanding Bodies: Art, Cities, Environment - Proceedings of the ACADIA 2007 Conference, 2007; pp. 130-137.
23. Kirchbuchner, F.; Grosse-Puppendahl, T.; Hastall, M.R.; Distler, M.; Kuijper, A. Ambient Intelligence from Senior Citizens' Perspectives: Understanding Privacy Concerns, Technology Acceptance, and Expectations. In *Ambient Intelligence, Ami 2015*, DeRuyter, B., Kameas, A., Chatzimisios, P., Mavrommati, I., Eds.; Lecture Notes in Computer Science; 2015; Volume 9425, pp. 48-59.
24. Zimmermann, V.; Gerber, P.; Marky, K.; Böck, L.; Kirchbuchner, F. Assessing users' privacy and security concerns of smart home technologies. *i-com* **2020**, *18*, 197-216, doi:10.1515/icom-2019-0015.
25. Coughlin, J.F.; Ambrosio, L.A.D.; Reimer, B.; Pratt, M.R. Older Adult Perceptions of Smart Home Technologies: Implications for Research, Policy & Market Innovations in Healthcare. In Proceedings of the 2007 29th Annual International Conference of the IEEE Engineering in Medicine and Biology Society, 22-26 Aug. 2007, 2007; pp. 1810-1815.
26. Zwierenberg, E.; Finnema, E.; Dijkstra, A.; Hagedoorn, M.; Sanderman, R. Diffusion of assistive technology among older people: A case of the House of the Present. *Gerontechnology* **2018**, *16*, 242-248, doi:10.4017/GT.2017.16.4.006.00.
27. Grace, S.L.; Taherzadeh, G.; Chang, I.S.J.; Boger, J.; Arcelus, A.; Mak, S.; Chessex, C.; Mihailidis, A. Perceptions of seniors with heart failure regarding autonomous zero-effort monitoring of physiological parameters in the smart-home environment. *Heart & Lung* **2017**, *46*, 313-319, doi:10.1016/j.hrtlng.2017.04.007.
28. Offermann-van Heek, J.; Ziefle, M. Nothing Else Matters! Trade-Offs Between Perceived Benefits and Barriers of AAL Technology Usage. *Frontiers in Public Health* **2019**, *7*, doi:10.3389/fpubh.2019.00134.
29. Singh, D.; Psychoula, I.; Kropf, J.; Hanke, S.; Holzinger, A. Users’ perceptions and attitudes towards smart home technologies. *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)* **2018**, *10898 LNCS*, 203-214, doi:10.1007/978-3-319-94523-1_18.
30. Liu, N.; Purao, S.; Tan, H.P. Value-inspired service design in elderly home-monitoring systems. In Proceedings of the 2016 IEEE International Conference on Pervasive Computing and Communication Workshops, PerCom Workshops 2016, 2016.
31. Schroeter, C.; Mueller, S.; Volkhardt, M.; Einhorn, E.; Huijnen, C.; Heuvel, H.v.d.; Berlo, A.v.; Bley, A.; Gross, H. Realization and user evaluation of a companion robot for people with mild cognitive impairments. In Proceedings of the 2013 IEEE International Conference on Robotics and Automation, 6-10 May 2013, 2013; pp. 1153-1159.
32. Stefanov, D.H.; Zeungnam, B.; Won-Chul, B. The smart house for older persons and persons with physical disabilities: structure, technology arrangements, and

perspectives. *IEEE Transactions on Neural Systems and Rehabilitation Engineering* **2004**, *12*, 228-250, doi:10.1109/TNSRE.2004.828423.
33. Jusob, F.R.; George, C.; Mapp, G. Exploring the need for a suitable privacy framework for mHealth when managing chronic diseases. *Journal of Reliable Intelligent Environments* **2017**, *3*, 243-256, doi:10.1007/s40860-017-0049-7.
34. Hensel, B.K.; Demiris, G.; Courtney, K.L. Defining obtrusiveness in home telehealth technologies: A conceptual framework. *Journal of the American Medical Informatics Association* **2006**, *13*, 428-431, doi:10.1197/jamia.M2026.
35. Majumder, S.; Aghayi, E.; Noferesti, M.; Memarzadeh-Tehran, H.; Mondal, T.; Pang, Z.; Deen, M.J. Smart Homes for Elderly Healthcare-Recent Advances and Research Challenges. *Sensors* **2017**, *17*, doi:10.3390/s17112496.
36. Ding, D.; Cooper, R.A.; Pasquina, P.F.; Fici-Pasquina, L. Sensor technology for smart homes. *Maturitas* **2011**, *69*, 131-136, doi:10.1016/j.maturitas.2011.03.016.
37. Sánchez, V.G.; Taylor, I.; Bing-Jonsson, P.C. Ethics of smart house welfare technology for older adults: A systematic literature review. *International Journal of Technology Assessment in Health Care* **2017**, *33*, 691-699, doi:10.1017/S0266462317000964.
38. Pal, D.; Triyason, T.; Funilkul, S.; Ieee. *Smart Homes and Quality of Life for the Elderly: A Systematic Review*; 2017; pp. 413-419.
39. Demiris, G.; Hensel, B.K. Technologies for an aging society: a systematic review of "smart home" applications. *Yearbook of medical informatics* **2008**, 33-40, doi:10.1055/s-0038-1638580.
40. Mittelstadt, B. Ethics of the health-related internet of things: a narrative review. *Ethics and Information Technology* **2017**, *19*, 157-175, doi:10.1007/s10676-017-9426-4.
41. Marikyan, D.; Papagiannidis, S.; Alamanos, E. A systematic review of the smart home literature: A user perspective. *Technological Forecasting and Social Change* **2019**, *138*, 139-154, doi:10.1016/j.techfore.2018.08.015.
42. Peruzzini, M.; Germani, M. Design of a service-oriented architecture for AAL. *International Journal of Agile Systems and Management* **2016**, *9*, 154-178, doi:10.1504/IJASM.2016.078582.
43. Kowalski, J.; Skorupska, K.; Kopeć, W.; Jaskulska, A.; Abramczuk, K.; Biele, C.; Marasek, K. Older adults and voice interaction: A pilot study with google home. In Proceedings of the Conference on Human Factors in Computing Systems - Proceedings, 2019.
44. Etemad-Sajadi, R.; Dos Santos, G.G. The impact of connected health technologies on the quality of service delivered by home care companies: Focus on trust and social presence. *Health Marketing Quarterly* **2020**, doi:10.1080/07359683.2020.1763096.
45. Lee, E.J.; Park, S.J. A framework of smart-home service for elderly's biophilic experience. *Sustainability (Switzerland)* **2020**, *12*, 1-26, doi:10.3390/su12208572.
46. Astell, A.J.; McGrath, C.; Dove, E. 'That's for old so and so's!': does identity influence older adults' technology adoption decisions? *Ageing & Society* **2020**, *40*, 1550-1576, doi:10.1017/s0144686x19000230.
47. Tabachnick, B.G.; Fidell, L.S. Using multivariate statistics . Northridge. *Cal.: Harper Collins* **1996**.
48. Gratz, K.L.; Roemer, L. Multidimensional assessment of emotion regulation and dysregulation: Development, factor structure, and initial validation of the difficulties in emotion regulation scale. *Journal of psychopathology and behavioral assessment* **2004**, *26*,

41-54.

49. Woosnam PhD, K.M.; Norman PhD, W.C. Scale Development and Factor Structure Confirmation of Constructs within Durkheim's Theoretical Framework of Emotional Solidarity. **2016**.

50. Fornell, C.; Larcker, D.F. Evaluating structural equation models with unobservable variables and measurement error. *Journal of marketing research* **1981**, *18*, 39-50.

Chapter 6
Technology acceptance model of smart homes for the elderly

Chapter 6
Technology acceptance model of smart homes for the elderly

6.1 Research purpose

The traditional technology acceptance model takes perceived usefulness and perceived ease of use as the core variables. However, with the development and popularity of information communication technology, smart technology has been used and served for all aspects of human demands. The application value of technology today is not only for usability, but also for emotion, social interaction, dignity and respect, self-realization, etc. The behavioral intention to use of emerging technology is not only related to the ease of use, but also influenced by a quite number of other factors, such as privacy, safety, individual psychology, subjective norms, market maturity, government policies, etc. Therefore, the conventional technology acceptance model has its limitation to respond the advancement of complex society and comprehensive integration of technological application nowadays. Although there are considerable numbers of scholars and researchers proposed and expanded some new models based on the classic one, they failed to present the influencing factors in a systematic way. Two crucial issues remain to be resolved, the first is "how does the technology acceptance model respond to users' diverse value demands regarding the dramatic changes of information communication technology in this era? " . The second is "how to reflect the technology negative aspects as well as its positives in a technology acceptance model at the same time to grasp its all-around development status? " This chapter explored the above two issues in detail. The author believes that, although the development and iteration of smart technology update rapidly, but the essential significance of technological development is to realize the comprehensive wellbeing and sustainable development of mankind. Therefore, the construction of the technology acceptance model should take the human value perception as the core variable, and at the same time, avoid, reduce, and control their perceived risk in different levels as much as possible. Thus, this chapter aims to build a smart homes technology acceptance model for future elderly based on perceived value and perceived risk, their measurement items are extracted from the former chapters.

6.2 Research methods

This chapter follows the standard empirical research process. The main research methods are literature analysis, questionnaire survey, statistical analysis, and structural equation modeling. The research steps are as follows: First, on the basis of literature research, the research hypothesis in this chapter was proposed and a hypothetical model was constructed. The model involves five variables: perceived benefit, perceived cost, perceived risk, attitude toward using, behavioral intention to use, among which perceived benefit and perceived cost come together to form the perceived value. The measurements of perceived benefit, perceived cost, and perceived risk used the scale developed in the previous chapters, and the items of attitude toward using and behavioral intention to use were extracted from the existing literature. Afterwards, all the measurement items were compiled to a preliminary questionnaire. A pre-study was conducted to test the consistency and reliability of the questionnaire. Depends on the result, the questionnaire has been optimized before large scale distribution. Then, the main survey was conducted through online questionnaire platform, Wenjuanxing. After finishing the data collection, the reliability and validity of the collected responses were tested and descriptive statistical analysis was performed via SPSS 25.0. Last but not least, AMOS 25.0 was used to draw the technology acceptance model through structural equation model, model fitness test and path analysis was conducted, the rationality of the seven hypotheses were verified.

6.3 Hypotheses development and framework

6.3.1 Perceived value

This study follows Zeithaml's academic propositions and basically divides perceived value into perceived benefit and perceived cost.

6.3.1.1 Perceived benefit

Perceived benefit is the core manifestation of perceived value. In the current fiercely competitive market environment, if an enterprise wants to achieve development and gain long-term prosperity, they must adhere to user-centered principal and highlight the corporate strategy of value creation to satisfy customer demands as much as possible. Enterprises should formulate reasonable and effective product prices based on the resources they invest according to the internal operating conditions and external market environment, and enhance the perceived benefit to maximize the perceived value of their products and services. Essentially, what companies sell and deliver is not products or services, but value, the value that contains in the product functions and service delivery which can be perceived by consumers through their existing experience and cognition. Regarding the smart homes system for the elderly, the higher the benefit that the system can bring to the elderly, the more the value demands of the elderly can be met, so it will have positive effect on their attitude toward using and further increase their behavioral intention to use. Based on the above analysis, we propose the following two hypotheses:

Hypothesis 4 (H4). *Perceived benefit positively affects the attitude toward using.*

Hypothesis 5 (H5). *Perceived benefit positively affects the behavioral intention to use.*

6.3.1.2 Perceived cost

The usage of smart home products and services requires users to pay corresponding cost. In Chapter 4, the author divides the perceived cost of smart homes for the elderly into three aspects, namely monetary cost, study cost, space cost. The monetary cost mainly includes the money that users need to pay during the purchase, transportation, installation, usage, and maintenance of related products and services; study cost is the time, energy, physical strength and cognitive investment that elderly users need to spend for using related products and services; space cost is the cost related to the original home layout and space changes. To sum up, perceived cost is what users must pay for the perceived benefit they want to acquire from the smart home systems. The higher the perceived cost is, the higher the cost will be paid to obtain relevant benefits. That also means, the relative perceived benefit and value will be reduced and perceived risk will increase. Based on the analysis above, the author drew the following hypotheses:

Hypothesis 1 (H1). *Perceived cost negatively affects the perceived benefit.*

Hypothesis 2 (H2). *Perceived cost positively affects the perceived risk.*

6.3.2 Perceived risk

The perceived risk of smart home is the uncertainty and harmful factors that elderly people may encounter during the purchasing, using and maintaining process of related smart home products and services. In Chapter 5, the author defines the perceived risk of smart homes for the elderly from macroscopic laws, policies, and industries, to microscopic privacy, security, performance, and services. It mainly includes privacy & security risk, physical risk, technological risk, performance risk, service risk, financial risk, psychological risk, industrial & market risk, social support risk, policy and law risk. The perceived risk will exert obvious negative effects on perceived benefit. The greater the perceived risk is, the more serious its damage to perceived benefit which will further negatively affect the users' attitude toward using. Based on the analysis above, the author puts forward the following hypotheses:

Hypothesis 3 (H3). *Perceived risk negatively affects the perceived benefit.*

Hypothesis 6 (H6). *Perceived risk negatively affects the attitude toward using.*

6.3.3 Attitude toward using

Attitude toward using is the consumers judgment, feeling and preference toward the using of smart homes. It exists at the level of consciousness. Consciousness is the forerunner of behavior intention, which stimulates and guides the occurrence of behavior. Based on the above analysis, the author gives the following assumption:

Hypothesis 7 (H7). *Attitude toward using positively affects the behavioral intention to use.*

The following is the hypotheses framework of the technology acceptance model of smart homes for future elderly, as shown in Figure 6.1.

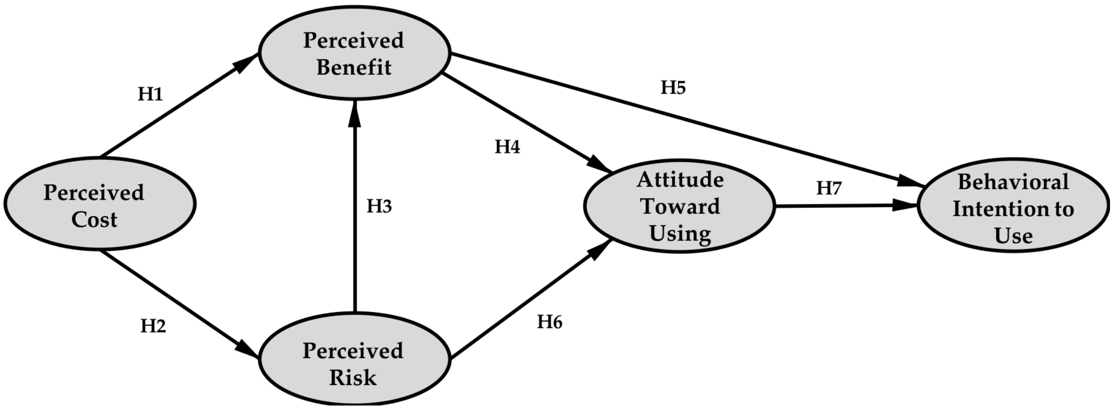

Figure 6.1. The hypotheses framework of technology acceptance model

6.4. Empirical study

6.4.1 Measurement development

The study involves five variables: perceived benefit, perceived cost, perceived risk, attitude toward using, and behavioral intention to use, among which the perceived benefit, perceived cost could be combined and stand for perceived value. The perceived value and perceived risk in this study used the scale developed in the former chapters, while the variable of intention to use and usage behavior are all extracted from the previous study, and the specific content are shown in Table 1. All the questions have been give a specific condition "When you getting old" and items have been measured in 5-point Likert scale, during which "1" is "strongly disagree", "2" is "disagree", "3" is "general", "4" is "agree", and "5" "is "strongly agree".

Table 1. The measurement items of smart homes technology acceptance model for the elderly

Variable	Label	Items
Independence (IND)	IND1	Smart homes can help me realize self-reliance.
	IND2	Smart homes can help me realize self-care.
	IND3	Smart homes can help me realize self-management.
	IND4	Smart homes can help me improve daily life efficiency.
	IND6	Smart homes can provide products and services to help with my weaken ability.
Healthcare (HEA)	HEA1	Smart homes can detect my health data and give timely feedback to me.
	HEA2	Smart homes can let me exercise at home and realize disease prevention.
	HEA4	Smart homes can provide telemedicine services for me.
	HEA6	Smart homes can help me with the rehabilitation if I got serious disease or finished surgery.
	HEA7	Smart homes can help me keep in contact with my medical administration.
Safety (SAF)	SAF1	Smart homes can ensure my life's safety.
	SAF3	Smart homes can ensure my environmental safety.
	SAF4	Smart homes can ensure my property safety.
Positive emotion (PE)	PE1	Smart homes can enable me to feel comfortable.
	PE2	Smart homes can enable me to feel relaxed.
	PE3	Smart homes can enable me to feel calm.
	PE4	Smart homes can enable me to feel joyful.
	PE5	Smart homes can enable me to feel delighted.
	PE6	Smart homes can enable me to feel excited.
	PE7	Smart homes can enable me to feel I am loved.
Engagement (ENG)	ENG1	Smart homes can provide me with competent tasks.
	ENG2	Smart homes can provide me with the support of my interest development.
	ENG3	Smart homes can enable me to learn knowledge and skills which I want to learn.
	ENG4	Smart homes can enable me to get the state of absorption and concentration.
	ENG5	Smart homes can enable me lose track of time and space while doing something I enjoy.
Relationship	REL1	Smart homes can provide the functions and services to increase the family interaction.
	REL2	Smart homes can strengthen my social life and cultivate connections to others.
	REL3	Smart homes can provide me with companionship.

(REL)	REL4	Smart homes can provide the functions and services to help me strengthen the connection with my belief.
	REL6	Smart homes can provide the functions and services to provide biophilic experience for and strengthen the connection with nature.
Meaning (MEA)	MEA1	Smart homes can make me feel I have a sense of direction and purpose in my life.
	MEA2	Smart homes can help me to do family responsibilities.
	MEA3	Smart homes can enable me to make social contributions via technology and Internet.
	MEA4	Smart homes can help me do some things which I could not do when I am young via smart technology.
	MEA5	Smart homes can enable me to do re-employment via technology and the Internet.
Achievement (ACH)	ACH1	Smart homes can help me make progress in life.
	ACH2	Smart homes can help me achieve my goals.
	ACH6	Smart homes can help me have a sense of accomplishment in life.
Monetary Cost (MON)	MON 1	If I want to use smart home when I am old, I need to buy related products and equipment.
	MON2	If I want to use smart home when I am old, I need to pay for related services.
	MON3	If I want to use smart home when I am old, I need to pay for installation fee.
	MON4	If I want to use smart home when I am old, I need to pay for maintenance fee.
	MON5	If I want to use smart home when I am old, I need to pay for transportation fee.
Study Cost (STU)	STU1	If I want to use smart home when I am old, I need to spend time learning how to use it.
	STU2	If I want to use smart home when I am old, I need to spend money learning how to use it.
	STU3	If I want to use smart home when I am old, I need to spend energy learning how to use it.
	STU4	If I want to use smart home when I am old, I need to seek for others help to teach me how to use it.
	STU5	If I want to use smart home when I am old, I need to learn related legislation and regulations.
	STU6	If I want to use smart home when I am old, I need to learn related industry standardization.
Space Cost (SPA)	SPA1	If I want to use smart home when I am old, I need to change the arrangement of my house.
	SPA2	If I want to use smart home when I am old, I need to change the decoration of my house.
	SPA3	If I want to use smart home when I am old, I need to remove the old equipment and furniture in my house.
	SPA4	If I want to use smart home when I am old, I need to rearrange the network layout of my house.
Privacy & Security risk (PS)	PS1	I don’t like the feeling of surveillance.
	PS2	I don’t like to share my personal daily life activities with others.
	PS3	I don't like to share my sensitive personal health information data with my important person.
	PS4	I am worried about the ownership of my personal data and information.
	PS5	I am worried that my personal data and information may be misused without my permission.

	PS6	I am worried about the unauthorized access to my personal data and information and for what purposed it is being used.
	PS7	I am worried that the smart homes system has loopholes and might be attacked by hacker.
Physical risk (PHY)	PHY1	I am worried that using smart homes will increase the risk of theft.
	PHY2	I am worried that using smart homes will increase the risk of robbery.
	PHY3	I am worried that using smart homes will increase the risk of blackmail and extortion.
	PHY4	I am worried that some devices or equipment may be lack of reliable physical quality and hurt me.
	PHY5	I am worried that the smart homes may provide me wrong information or conduct wrong command and bring harm to me.
	PHY6	I am worried that smart homes could not provide timely response and help when I encounter emergency problems.
	PHY7	I am worried that the usage and radiation of smart homes will bring unexpected health problems.
Technological risk (TECH)	TECH1	I am worried that the smart homes system could not identify or conduct my command accurately.
	TECH2	I am worried that the smart homes may have malfunctions or suboptimal performance.
	TECH3	I am worried that the smart homes may lack of reliability in the system.
	TECH4	I am worried that the smart homes will deliver wrong messages to related people or service staff.
	TECH5	I am worried that the smart homes devices and systems may have low expansion capability.
	TECH6	I am worried that the smart homes may lack of interoperability among different devices and heterogeneous systems.
	TECH7	I am worried that the smart homes technology update too fast and old-fashioned system may have low stability.
	TECH9	I am worried that the smart homes should conduct continuous machine learning and may lack of data to organize programme for me.
	TECH10	I am worried that the data management (record, storage, handling capability and compression) techniques are immature.
Performance risk (PER)	PER1	I am worried that the smart homes function is too unitary and may have poor usability.
	PER2	I am worried that the smart homes devices are obstruction or impediment in space and make me feel uncomfortable at home.
	PER3	I am worried that the smart homes devices are aesthetic incongruence which cannot integrate with my house environment.
	PER4	I am worried that the smart homes devices and systems have low accessibility and are hard to use.
	PER5	I am worried that the smart homes interface and interaction is lack of user friendliness for elderly people.
	PER7	I am worried that the smart homes have interference with my daily activities.
	PER8	I am worried that the smart homes may disrupt my daily routines.
	SER1	I am worried that the smart homes services are not reliable.
	SER2	I am worried that the smart homes services could not give me timely responses.
	SER3	I am worried that the smart homes services do not have assurance.

Service risk (SER)	SER4	I am worried that the smart homes services could not provide the consistent services according to their promise.
	SER5	I am worried that the smart homes services could not provide suitable and professional services.
	SER6	I am worried that the smart homes services could not provide personalized services I want.
	SER7	I am worried that the smart homes services staff could not treat me in a good manner.
	SER8	I am worried that the smart homes services staff is in low neatness and cleanness
	SER9	I am worried that the smart homes services staff could not understand my specific needs.
Financial risk (FIN)	FIN1	I am worried that the cost of smart homes products and services are beyond my affordability.
	FIN2	I am worried that the money I pay for smart homes doesn’t deserve its value.
	FIN3	I am worried that I will spend more money for its affordable services if I use smart homes.
	FIN4	I am worried that smart homes may bring me some non-essential financial expenditure.
	FIN5	I am worried that smart homes may increase my financial pressure.
Psychological risk (PSY)	PSY1	I am worried that my family will blame me on the usage of smart homes.
	PSY2	I am worried that my friends will think I am strange if I use smart homes.
	PSY3	I am worried that smart homes may cause of embarrassment or stigma when people visit my house.
	PSY4	I am worried that smart homes devices may be a burden to the people who live with me.
	PSY5	I am worried that smart homes may replace or diminish my human contact and result in social isolation.
	PSY6	I am worried that the smart homes will result in my reliance on automation technology and loss of autonomy
	PSY7	I am worried that the smart homes devices will always be perceived as reinforcing an image of being “old” for myself.
Industry & Market risk (IM)	IM1	I am worried that there is an absence of a comprehensive market.
	IM2	I am worried that there is no consistency standardization and regulation of the smart home industry.
	IM3	I am worried that the product update too fast and the products I brought would be obsolete soon.
	IM4	I am worried that there are no eligibility criteria about the enterprises and service providers quality and level.
	IM5	I am worried that the compatibility of different brands, systems, devices is terrible.
	IM6	I am worried that there is a shortage of service labor in related aging industry.
Social Support (SS)	SS2	I am worried that there is no enough support from caregivers.
	SS3	I am worried that there is no enough support from medical staff.
	SS5	I am worried that there is no enough support from my family.
	SS7	I am worried that there is no enough support from my friends.
	SS8	I am worried that there is no enough support from my neighborhood.
	SS9	I am worried that there is no enough support from my community.
	SS10	I am worried that there is no enough support from organizations and institutions.

Policy& Law risk (PL)	PL1	I am worried that there is a lack of policy or legal framework to give the standards and guidance.
	PL2	I am worried that there is a lack of policy & law conduct environment.
	PL3	I am worried that there is a lack of policy & law supervision environment.
	PL4	I am worried that there is a lack of policy & law to provide right assurance.
	PL5	I am worried that there is a lack of legal responsibilities and professional competence of service provider and caregivers.
	PL6	I am worried that there is a lack of legal aid if some accidence happened due to the technology or service problems.
Attitude Toward Using (ATU)	ATU1	When I am old, I believe that smart homes will help me aging in place.
	ATU2	When I am old, I believe that using smart homes will help me live a healthy lifestyle.
	ATU3	When I am old, I believe that using smart homes will improve my quality of life.
	ATU4	When I am old, I believe that using smart homes will bring happiness for me.
	ATU5	When I am old, I believe that it is worthwhile to use smart homes.
Behavioral Intention To Use (BIU)	BIU1	When I am old, I am willing to use smart homes.
	BIU2	When I am old, I plan to use smart homes.
	BIU3	When I am old, there is high probability that I will use smart homes.
	BIU4	When I am old, I will use smart homes as soon as I can.
	BIU5	When I am old, I will recommend my family or friends to use smart homes.

6.4.2 Survey procedure and data collection

After the measurement items were determined, the author translated them into Chinese, added the demographic information questions, and developed a preliminary questionnaire. The questionnaire was randomly distributed through the Chinese Internet questionnaire platform, Wenjuanxing. Investigation and data collection are mainly divided into two stages which including the pre-study test and the main study. In the first stage, we collected 159 initial questionnaire responses. Through the analysis of the data results, the question description language and overall logic were optimized to ensure that the respondents were more intuitive and accurate in obtaining the questions' meaning and options' setting. Based on the adjustment of the pre-study test, we determined the final questionnaire content and started large-scale online distribution. The detail content of the final questionnaire can be seen in Appendix C. In the end, a total of 664 formal responses were collected, and users with relevant experience in using intelligent products or smart homes devices aged from 45-60 were identified as targeted samples that met the research requirements. Under this standard, 557 valid responses were obtained as data samples for further analysis, with an effective rate of 83.9%.

6.4.3 Data analysis plans

For data analysis, the study initially conducted the descriptive analysis, reliability, and validity test. Then, model fit was examined to satisfy the relevant criteria. Last, SEM was performed to check path analysis for hypothesis evaluations. SPSS 25.0 was mainly responsible for summarizing the demographical information and the preliminary statistics, while AMOS 25.0 was mainly used to conduct factor analysis and path analysis.

In the process of data processing, there are two points that need to be specifically stated. First, because the variables involved in this model have both positive and negative variables, in order to maintain consistency, for data processing, the author applied reverse scoring for the perceived cost and perceived risk variables. To be more specific, the original "1" is "5", "2" is "4", "3" remains unchanged, "4" is "2", and "5" is "1". Second, since there are a quite number of corresponding items, as well as called observation variables in this model, if all of them are presented in AMOS 25.0, the model would appear too bloated and complicated. Therefore, the author used a method of packaging to deal with the measurement items of each variable. For example, there were five items of "Independence" factor in perceived benefit, the "Independence" factor was eventually presented by one observation variable "IND" instead of five different observation variables in detail in the structural equation modeling. And the author took the average value of all the five observation variables to represent the value of "IND" factor. To be more specific, if one response, its value of "IND 1" is"4", "IND 2" is"3", "IND 3" is"5", "IND 4" is"4", "IND 6" is"4", then the value of "IND" for that response is the sum of these five observation variables, 20, divided by the number of items, 5, equals 4. The value calculation of other observation variables and responses share the same process.

6.4.4 Demographic information

In the demographic information part, the study applied SPSS 25.0 to statistics basis information of the valid samples, including gender, age, education background, and monthly income, etc. Among the 557 samples, 303 are males, accounting for 54.4% of the total sample; 254 females, accounting for 45.6%. The detailed results are shown in Table 2.

Table 2. Demographic information for smart homes technology acceptance model

Attribute	Value	Freq.	%	Attribute	Value	Freq.	%
Gender	Male	303	54.4		<1000	46	8.3
	Female	254	45.6		1000-3000	142	25.5
Age	45-50	169	30.3	Monthly	3000-5000	133	23.9
	51-55	347	62.3	Income	5000-7000	156	28.0
	56-60	41	7.4	(RMB)	7000-10000	40	7.2
Education	<High school	196	35.2		10000+	40	7.2
	High school	107	19.2	Occupation	Teacher	29	5.2
	Associate	105	18.9		Civil Servant	31	5.6
	Bachelor	85	15.3		IT company staff	33	5.9
	Master	44	7.9		Non-IT company staff	154	27.6
	Doctor	20	3.6		Private entrepreneur	33	5.9
Marital	Single	75	13.5		Freelancer	22	3.9
status	Married	422	75.8		Worker	172	30.9
	Divorced	51	9.2		Farmer	29	5.2
	Widowed	9	1.6		Others	54	9.7

6.5 Results and findings

6.5.1 Descriptive analysis, reliability, and validity

Descriptive analysis was summarized in Table 3. For the reliability tests, Cronbach's alpha served as an indicator for measuring the internal consistency of the survey with a threshold of 0.7 [1]. The adequate reliability could reveal that items reflect similar observations under similar scenarios with similar participants [2]. For validity tests, unidimensionality validity, convergent validity, and discriminant validity served as indicators for confirmative factor analysis [3], which measures the degree of association between a claimed variable and its observed variables, as depicted in Table 3. Results indicated that all items had achieved sufficient validity. To specify, the threshold of standardized factor loadings and averaged variances expected (AVE) are both beyond 0.5 or above, and the composite reliability (C.R.) should be above 2 [4], indicating the current sample has achieved satisfactory validity. In addition, maximum shared variance (MSV) and average shared variance (ASV) were examined to check whether discriminant validity is adequate. The relevant results are shown in Table 4.

Table 3. Reliability and Unidimensionality.

Construct	Cronbach's Alpha	Variable	Mean	Standard Deviation	Standardized Factor Loading	C.R. (t-Value)	SMC	AVE	Composite Reliability
Perceived Benefit （PB）	0.916	IND	3.68	0.989	0.700	-	0.490	0.558	0.910
		HEA	3.71	0.961	0.745	28.336	0.555		
		SAF	3.76	1.006	0.759	26.954	0.575		
		PE	3.85	0.988	0.757	19.115	0.573		
		ENG	3.78	0.976	0.760	19.346	0.578		
		REL	3.80	1.002	0.749	18.928	0.562		
		MEA	3.75	0.981	0.767	19.633	0.588		
		ACH	3.72	0.948	0.735	18.686	0.540		
Perceived Cost （PC）	0.837	MON	2.36	1.045	0.736	-	0.542	0.568	0.798
		STU	2.36	1.064	0.761	28.336	0.579		
		SPA	2.42	1.025	0.764	26.954	0.584		
Perceived Risk （PR）	0.934	PS	2.41	0.962	0.708	-	0.501	0.572	0.930
		PHY	2.35	0.981	0.717	20.632	0.514		
		TECH	2.24	1.132	0.783	21.240	0.614		
		PER	2.32	1.107	0.792	21.516	0.628		
		SER	2.40	0.990	0.732	19.406	0.536		
		FIN	2.36	1.048	0.719	18.939	0.517		
		PSY	2.34	1.024	0.765	20.486	0.585		
		IM	2.40	1.079	0.738	19.594	0.545		
		SS	2.27	1.102	0.780	21.118	0.609		
		PL	2.34	1.082	0.822	22.760	0.676		
Intention to Use （ITU）	0.892	ITU1	3.53	1.105	0.837	-	0.701	0.618	0.889
		ITU2	3.41	1.059	0.744	19.351	0.554		
		ITU3	3.50	1.040	0.696	17.888	0.484		
		ITU4	3.45	1.042	0.754	19.912	0.569		
		ITU5	3.47	1.058	0.885	25.040	0.783		
Usage Behavior （UB）	0.890	UB1	3.85	1.084	0.724	-	0.525	0.598	0.881
		UB2	3.77	1.023	0.787	17.166	0.620		
		UB3	3.97	1.091	0.697	18.030	0.486		
		UB4	3.80	1.026	0.822	17.317	0.675		
		UB5	3.79	1.035	0.830	16.948	0.689		

Note: C.R.(t-value)=composite reliability; SMC=square multiple correlations; AVE=averaged expected.

Table 4. Correlation Matrix of the Constructs.

Construct	CR	AVE	MSV	ASV	PB	PC	PR	ITU	UB
PB	0.910	0.558	0.206	0.103	0.747				
PC	0.798	0.568	0.076	0.036	-0.230***	0.754			
PR	0.930	0.572	0.206	0.104	-0.454***	0.276***	0.756		
ATT	0.889	0.618	0.101	0.066	0.258***	-0.103***	-0.318***	0.786	
INT	0.881	0.599	0.088	0.054	0.297***	-0.079***	-0.182***	0.294***	0.774

Note: p < 0.1; ** p < 0.05; *** p < 0.01; MSV stands for the maximum shared variance; ASV stands for average shared variance.

6.5.2 Model fit

Regarding the model fit, the goodness-of-fit (GFI) severed as an indicator by the following indices [5], namely standardized root means square residual (SRMR), goodness-of-fit index (GFI), root mean square error of approximation (RMSEA), normed fit index (NFI), incremental fit index (IFI), Tucker–Lewis index (TLI), and comparative fit index (CFI). All the indices have achieved sufficient fitness within the thresholds, as shown in Table 5.

Table 5. Goodness-of-Fit Test.

Category	Measure	Acceptable Values	Value
Absolute fit indices	Chi-square		479.9
	d.f.		238
	Chi-square/d.f.	1-5	2.016
	GFI	0.90 or above	0.922
	SRMR	0.08 or below	0.025
	RMSEA	0.05 - 0.08	0.046
Incremental fit indices	NFI	0.90 or above	0.928
	IFI	0.90 or above	0.963
	TLI	0.90 or above	0.956
	CFI	0.90 or above	0.962

Note: GFI = goodness-of-fit index; SRMR = standardized root mean square residual; RMSEA = root mean square error of approximation; NFI = normed fit index; IFI = incremental fit index; TLI = Tucker–Lewis index; CFI = comparative fit index.

6.5.3 Hypothesis testing and path analysis

As to test hypothesis 1-7, a path analysis was further conducted via structural equation model (SEM) to evaluate the association among various factors[6]. SEM in this study is a systematic approach to examine research hypotheses holistically [6]. Figure 6.2 and Table 6 show the results of path analysis and the examination of hypotheses 1-7.

Table 6. Hypothesis Testing

	Path Direction	Standardized coefficient	Standard error	C.R. (t-value)	Result
H1	PC - > PB	-0.114**	0.043	-2.585	Accepted
H2	PC - > PR	0.276***	0.042	6.071	Accepted
H3	PR - > PB	-0.422***	0.050	-8.983	Accepted
H4	PB - > ATU	0.143**	0.068	2.774	Accepted
H5	PB - > BIU	0.237***	0.054	4.871	Accepted
H6	PR - > ATU	-0.254***	0.071	-5.001	Accepted
H7	ATU - > BIU	0.233***	0.041	4.786	Accepted

Note: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

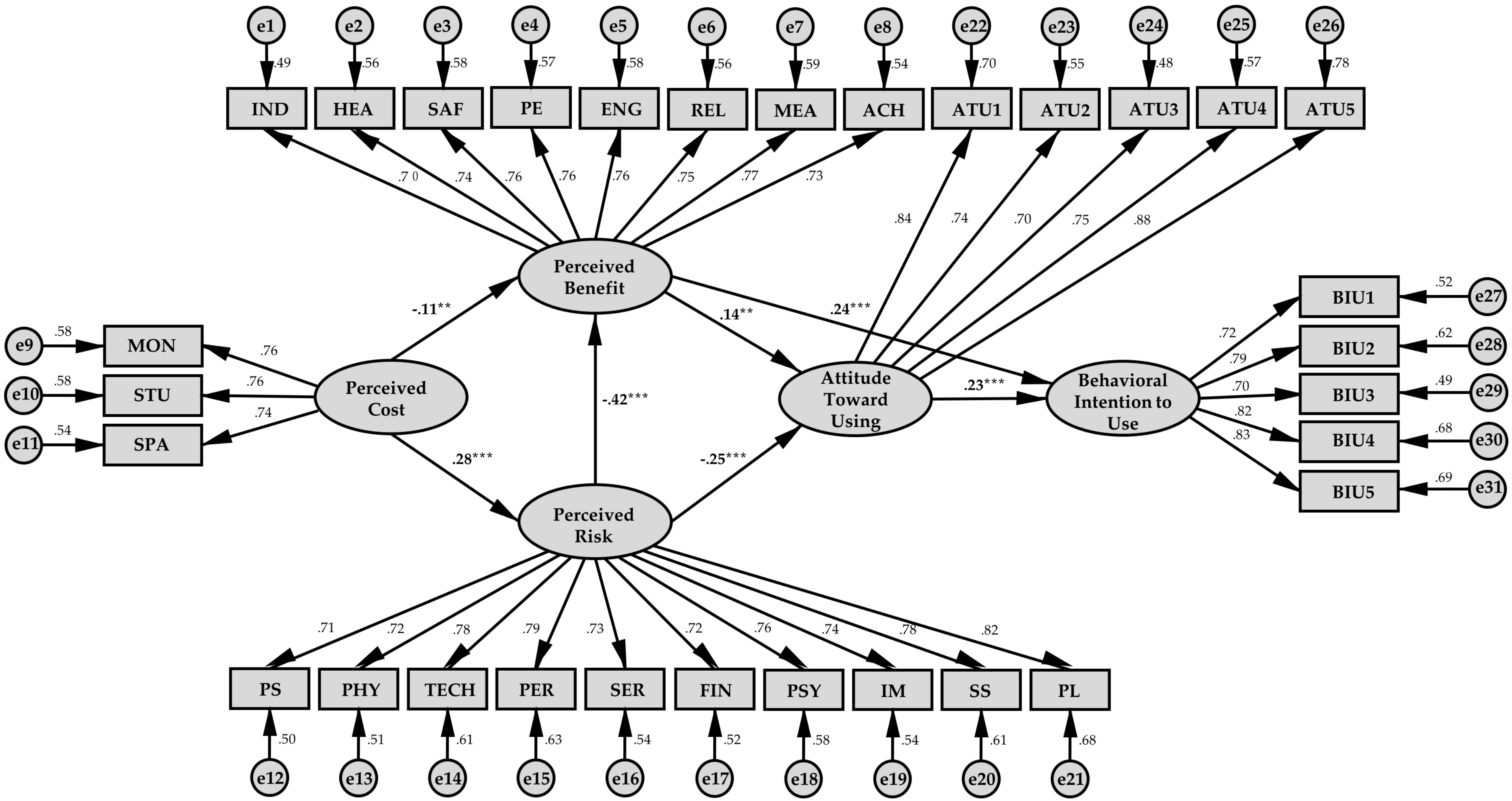

Figure 6.2. Path coefficients resulting from structural equation modeling (SEM)

Note: * p<0.1; ** p<0.05; ***p<0.01

6.6 Conclusion and discussion

From the results of the model fit test and hypothesis verification, we can see that the perceived value is determined by the perceived cost and the perceived benefit. The perceived value and the perceived risk will work together on the attitude of future elders toward smart home using, and the attitude toward using will further affect the behavioral intention to use of the elderly. Among them, the perceived cost has a negative effect on perceived benefit and a positive effect on perceived risk. This is because the perceived cost is the monetary, study, and space cost that elderly people need to pay for their usage of smart home products and services. The greater the cost they need to pay, the more they will sacrifice in order to gain the benefit from corresponding products and services, which also means the smaller the perceived benefit for the relevant products and services they will form. At the same time, the greater the cost also means the uncertainty of using relevant products and services is greater, so that the perceived risk will be further increased. Essentially, perceived cost is the beginning of the perceived benefit and perceived risk, because only when the customers expect the transaction to happen, they will calculate the invisible benefit they can get and be prepared for the uncertainty they may face. Hypothesis H1 (Path efficient= -0.11, $p<0.01$) and H2 (Path efficient=0.28, $p<0.001$) are verified. Perceived risk has a negative effect on perceived benefit. The level of risk will have an important impact on the evaluation of perceived benefit. The greater the perceived risk of smart home products and services is, the smaller the benefit the customers will perceive. Hypothesis H3 (Path efficient=-0.42, $p<0.001$) is verified. Perceived risk and perceived benefit are the two core determinants of elderly users' attitude toward using. Among them, perceived benefit is the core component of the perceived value of smart homes, which has a significant positive effect on the elders' attitude toward using and behavioral intention to use. Perceived risk has a significant negative effect on attitude toward using; H4 (Path efficient=0.14, $p<0.01$), H5 (Path efficient=0.24, $p<0.001$), H6 (Path efficient=-0.25, $p<0.001$) are verified. Consciousness is the forerunner of behavior, and attitude toward using has a significant positive effect on behavioral intention to use. H7 (Path efficient=0.23, $p<0.001$) has been verified.

Based on the discussion above, we will find that the perceived benefit is the core value variable in this model, the perceived cost and perceived risk in the model are two variables with essential negative effects. According to the principle of maximizing the positive effect and minimizing the negative effect as much as possible, the author proposes three core principles to improve the acceptance of smart home for the elderly:

6.6.1 Maximize perceived benefit

In this model, perceived benefit is the most core positive variable of perceived value that ultimately promotes attitude toward using and behavioral intention to use. Therefore, to increase the acceptance of smart home technology for the elderly, one of the most important principles should be maximizing perceived benefit. The perceived benefit in this study takes the PERMA-V wellbeing model as theory basis, and are further divided into 8 dimensions, namely, "Independence", "Healthcare", "Safety", "Positive emotion", "Engagement", "Relationship", "Meaning", "Achievement". To maximize perceived benefit, that is, to maximize the omni-directional well-being of the elderly in the smart home environment which also means to improve the product function and service ability of the smart home system in these eight dimensions and ensure the relevant quality.

- Independence: The benefit of "independence" contains five items，means that smart homes should bring efficiency and convenience to healthy or mildly disabled elders through smart products and services to help them get rid of dependence on others, achieve self-reliance, self-management, self-care, improve daily life efficiency and provide the help with their weaken ability. It mainly reflected in the home smart technology to meet the basic needs of the elderly, including clothing, eating, housing, moving, and using, such as the automatic control of home appliances, online shopping, take-out foods, taxi calls, picking up express delivery, washing clothes, housekeeping services, etc.
- Healthcare: The benefit of "healthcare" contains five items, means that smart homes should help the elderly realize the management, prevention, treatment and rehabilitation of healthy problems and diseases in home environment to live a healthy lifestyle through smart products and services. It mainly includes the detection and management of physical health through smart medical equipment, online medical consultation, telemedicine, embedded fitness equipment, rehabilitation training equipment, etc.
- Safety: The benefit of "safety" contains three items, means that smart homes should ensure the physical safety, environmental safety, and property safety of the elderly through smart products and services. Among them, the physical safety of the elderly mainly reflects by the emergency detection and responses, such as sudden heart attacks, falls, etc. Property safety is mainly reflected from the anti-theft monitoring system through smart doors, windows, cameras, etc. Environmental safety is mainly reflected by the monitor of air, water, electricity, fire, etc. in the home environment to prevent accidents such as gas leak and fire disaster.
- Positive emotion: The benefit of "positive emotion" contains seven items, means that smart homes should help the elderly maintain good emotions status through smart products and services, making them feel comfortable, relax, calm, joyful, delighted, excited, loved, and get rid of negative emotions such as loneliness or depression. It mainly includes two aspects. On the one hand, smart home could provide smart home theater, smart game equipment, smart party system, etc. to enable the elderly to engage in different entertainment and social activities, such as listening to music and radio, watching TV series, watching movies, playing chess and card games, family gatherings, etc. On the other hand, smart home could integrate lighting systems, temperature and humidity control systems, door and window systems, etc. to regulate the lighting, temperature, and humidity control to create a comfortable living environment for the elderly.
- Engagement: The benefit of "engagement" contains five items, means that smart homes should help the elderly to engage in activities related to their hobbies and competence in home life through smart products and services. The elderly could enter a state of “heart flow”, forgetting time and space, and feel unparalleled happiness from the things they are engaged in. The shaping of engagement mainly includes intelligent information system, intelligent education system, intelligent interest assistance system, etc., to help the elderly master, learn and engage in knowledge and activities that they are interested in.
- Relationship: The benefit of "relationship" contains five items, means that smart homes should help the elderly develop and strengthen their interpersonal bond with the outside world and promote their social interaction through smart products and services. The main objects include their relatives, friends, families, children, couple, pets, related

organizations and institutions. Moreover, it can also include the enhancement of the belief or religious connection of the elderly, the development of social companion robots based on artificial intelligence technology, and even the connection with nature through surroundings or the use of virtual reality to enhance their biophilic experience.

- Meaning: The benefit of "meaning" contains five items, means that smart homes should help the elderly to find the purpose and direction of life, provide opportunity to allow them continue making social contribution or reemployment to realize their value of existence after retirement. For example, using the Internet technology and platform to help them achieve re-employment, do freelance work, create start-ups, join online volunteer community to contribute to society, provide remote peers support, help children take care of grandchildren, master knowledge and skills through online study to complete unfulfilled wishes, etc.

- Achievement: The benefit of "achievement" contains three items, means that smart homes should help the elderly to make progress in life, achieving goals and accomplish what they can do to gain a sense of accomplishment. For smart homes, it can be mainly reflected in the sense of reality achievement and virtual achievement. The sense of reality achievement includes helping the elderly to be appreciated, concerned, and gain the recognition and respect from others or acquire social status through their hobbies, talents, works, etc. The sense of virtual achievement is mainly reflected in the smart home helping the elderly to get likes, comments, fans, and attention on the Internet platform or social media, even in virtual game system to obtain high rank of game character or virtual gaming wealth, etc.

6.6.2 Reduce the perceived cost

In order to enhance the perceived value of smart homes for the elderly which are reflected in the perceived benefit and perceived cost, according to the technology acceptance model, the perceived cost should be controlled and reduced in these three aspects:

- Monetary cost: The "Monetary cost" contains five items, refers to the money that the elderly need to pay during the purchase, transportation, installation, usage, maintenance process of relevant smart home products and services. To reduce monetary, smart home manufacturers and developers are required to consider the purchasing and payment capabilities of the vast majority of the elderly, reducing product development, transportation, assembly, and maintenance cost as much as possible, providing high quality products and services as well as giving a preferential price.
- Study cost: The "Study cost" contains six items, refers to the time, energy, money, intelligence investment of the elderly to learn the usage and operation of related products, equipment, and service systems. As the elderly getting older, their physical strength and intelligence will decrease which will bring different difficulties for them to accept and reflect new things. Therefore, smart homes for the elderly should take their cognitive characteristics and operation habits into consideration, provide them user-friendly operation methods, deliver information intuitively and directly, avoid redundant and complicated functions, so as to improve the accessibility and user experience to reduce their study cost.

- Space cost: The "Space cost" contains four items, refers to the investment that the elderly need to pay for changing the original arrangement of the living environment, removing and discarding of old products and equipment, redecoration and rearrangement of network layout in order to use smart home products and services. Reducing space cost requires smart home products and services for seniors, maximize the usage of original products and living environment of the elderly, and integrating new products and equipment into their original living environment. For example, installing sensors to make the original home products become intelligent and providing light modification services for interior decoration to avoid large-scale discard and re-decoration.

6.6.3 Control, avoid and eliminate perceived risk

In this model, perceived risk includes ten dimensions, namely privacy & security risk, physical risk, technological risk, performance risk, service risk, financial risk, psychological risk, industry & market risk, social support risk, and policy & law risk. The sources of perceived risk in smart homes for the elderly are multi-level and multi-faceted, including the physical and psychological characteristics of users themselves, technical and service issues of products and systems, industry norms and market immaturity, social support systems, government and national laws and regulations, etc., Among them, some can be controlled, some can be avoided, and some can be eliminated. Essentially, perceived risk contains multi-level issues ranging from individuals, enterprises, industries, society to the government. Therefore, the control, reduction and elimination of related risk requires the cooperation and strength from all different levels and fields.

- Privacy & Security risk: The "Privacy & Security risk" contains seven items, means that smart homes should try to remove the elderly's feeling of surveillance, protect their privacy and security of daily life activities, sensitive personal health information data, ownership of their personal data and information, take actions to avoid possible leakage or abuse of users' personal information and data due to system running or security issues in the process of monitoring user activities, health status and home environment.
- Physical risk: The "Physical risk" contains seven items, means that there are potential personal safety hazards and accident brought by smart home systems for the elderly during the usage process. It is mainly reflected in possible theft, robbery, blackmail and extortion, incorrect or untimely feedback of emergency, accidental injuries caused by equipment physical materials and shapes, invisible health problems caused by electromagnetic radiation. Emphasis and attention should be given to these aspects to protect the elderly's physical health and safety.
- Technological risk: The "Technological risk" contains nine items, refers to the risk which bringing by the immaturity, instability, inflexibility and incompatibility of smart home technology. It is mainly reflected in the low accuracy to recognize and conduct user commands, low system stability, system failures, false alarms, low expansion capability, incompatibility between different products and operating systems, poor data management and treatment ability. The smart home industry should engage in developing and optimizing the smart technology continuously to remove and reduce the technological risk for the elderly.
- Performance risk: The "Performance risk" contains seven items, mainly reflected in the unitary and poor usability, obstruction or impediment devices, aesthetic incongruence with the home environment, low accessibility and unfriendly operation, interference with daily activities. Reducing the performance risk means that the function design, appearance design, interaction design, user experience design, etc. of the smart home

system should fully consider the actual needs, operating habits, life routine, individual feelings of the elderly users to provide them user-friendly operation experience.

- Service risk: The "Service risk” contains nine items, means that smart homes for the elderly should provide high service reliability, timely response, enough quality assurance, consistency commercial promise, professional and competent service staffs (Good manner, neat and clean, empathy) for the elderly to meet the elderly’s demand and present high service quality.
- Financial risk: The "Financial risk”contains five items, refers to the pressure and uncertainty that users feel for their financial cost during the process of purchasing, using, and maintaining smart home products and services. It is mainly reflected in the relevant products and services are beyond the affordability of the elders, there is non-essential financial expenditure, the money spent doesn’t deserve its value, etc. Thus, make the price of smart homes meet the affordability of the majority of aging population and provide them with cost-effective products and services are important and necessary.
- Psychological risk: The "Psychological risk”contains seven items, refers to the pressure of external opinions and internal psychological barriers that users feel during the process of purchasing and using the smart home system. It is mainly reflected in the blame and incomprehension from important persons, unhealthy reliance on automation technology and loss of autonomy, persistent reminder about self-frailty, etc. Thus, the design and development of smart homes should fully consider the psychological characteristics of the elderly and give emphasis to avoiding relevant psychological problems and embarrassment.
- Industry & Market risk: The "Industry and market risk”contains five items, refers to the risk of immature and irregular market and industry development of smart homes for the elderly. It is mainly reflected in the market penetrations stays low and are far from mass adoption, no consistency industry standardization and regulation, no eligibility criteria about the products and services quality, the compatibility of different brands and products is poor, etc. Thus, actions should be taken in the industry and market level to control and reduce relevant risks, such as announce consistency industry standardization and regulation.
- Social support risk: The "Social support risk”contains seven items, mainly exists in the situation that the implementation of smart home products and systems need relevant social resources and forces, such as family support, peer support, community support, neighborhood assistance, institutional assistance, telemedicine services, emergency response etc., The lack of these kinds of support will bring relevant social support risk. Thus, the formation of a social support network for the elderly to support their daily life, healthcare and wellbeing should be given attention and emphasis.
- Policy & law risk: The "Policy & law risk”contains sixitems, means that the government or relevant public department and authorities should promulgate and issue effective policies and laws to regulate the smart home industry and provide guarantees for serving consumers. It is mainly reflected in the construction of legal framework, standards and guidance as well as mature policy & law conduction and supervision environment.

Reference

1. Hair, J.F.; Black, W.C.; Babin, B.J.; Anderson, R.E.; Tatham, R.L. Multivariate data analysis; Prentice hall Upper Saddle River, NJ: 1998; Volume 5.
2. Bilgin, Y. Qualitative Method Versus Quantitative Method in Marketing Research: An Application Example at Oba Restaurant. In Qualitative versus Quantitative Research; 2017.
3. Cleff, T. Univariate Data Analysis. In Exploratory Data Analysis in Business and Economics; 2014; pp. 23-60.
4. Cheung, M.F.Y.; To, W.M. The influence of the propensity to trust on mobile users' attitudes toward in-app advertisements: An extension of the theory of planned behavior. Computers in Human Behavior 2017, 76, 102-111, doi:10.1016/j.chb.2017.07.011.
5. Schiller, F. Should We Use SEM? Pros and Cons of Structural Equation Modeling. Methods of Psychological Research Online 2003, 8, 1-22.
6. Chen, N.; Zhao, M.; Gao, K.; Zhao, J. The Physiological Experimental Study on the Effect of Different Color of Safety Signs on a Virtual Subway Fire Escape-An Exploratory Case Study of Zijing Mountain Subway Station. Int J Environ Res Public Health 2020, 17, doi:10.3390/ijerph17165903.

Chapter 7
Conclusion

Chapter 7 Conclusion

This chapter gives a summary and conclusion about the whole dissertation, mainly including the following contents: research summary, conclusion, suggestions and advice for the development of smart homes for the elderly, limitation and future research direction.

7.1 Research summary

Smart home, as one of the most prosperous industries of the Internet of Things, has tremendous potential in helping the elderly aging in place, shaping a life with all-around wellbeing and dealing with the aging society challenges. However, compared with the optimistic estimates of related industry and academia, currently, the acceptance and market penetration of smart homes for the elderly stays extremely low. The essential problem is that the existing smart home products and services for older adults could not meet their core value demand, and the application of technology and service delivery have not been able to eliminate or reduce their worries and perceived risks. How to understand the core needs of the future elders and create a smart home environment that can provide the elderly with all-around happiness, reduce and avoid relevant risks as much as possible, and improve the acceptance and adoption of smart homes for future elders, has become a very valuable topic in the research field of aging society. As the most populous country in the world, China is one of the countries with the fastest aging process in the world. In the upcoming future, China will become the country with the most aging population globally which could bring huge burden to the Chinese government and society. This fact also reveals that there is an enormous blue ocean of business opportunities in Chinese aging industry. Targeted on the future elderly population aged from 45-60 in China, this research develops the perceived value and perceived risk scales of smart homes for future elders by following the standard scale development process. In addition, based on the development of perceived value and perceived risk scales, the study further develops a smart home technology acceptance model for the elderly by using perceived value and perceived risk as the core variables through structure equation modeling (SEM) in Amos 25.0. The following is the main content of this study.

- The perceived value scale development of smart homes for the elderly: The development of the perceived value scale takes the PERMA-V well-being model as theory basis. It reveals the core value needs of the elderly deeply and comprehensively and explores how smart home could bring all-around well-being to older adults from the physical, psychological, and cognitive perspectives. Happiness is an eternal goal pursued by human beings no matter how time changes and how technology advances. Thus, the value of technology application in aging field should aims at shaping all-around happiness to the elderly, especially for technology integration systems like smart homes. The perceived value scale is consisted of perceived benefit and perceived cost scale, among which the perceived benefit scale contains eight factors, they are independence(5), healthcare(5), safety(3), positive emotion(7), engagement(5), relationship(5), meaning(5) and achievement(3), in total 38 measurement items; the perceived cost scale is consisted of three factors, namely monetary cost(5), study cost(6) and space cost(4), in total 15 items. It can help related industries to fully and accurately grasp the core value demands of older adults and reduce their perceived cost as much as possible. The scale provides an important guidance and evaluation criteria for the development of related enterprises and industry in the future.

- The perceived risk scale development of smart home for the elderly: The development of perceived risk scale comprehensively analyzes and presents the risk factors affecting the elderly's perception and acceptance of smart homes from the macro to the micro perspective in China. Consumer's purchase behavior always company with uncertainty even serious and harmful consequence, they could not know whether their consumption decision is correct and whether the products and service could meet their expectation. Therefore, the perception toward this kind of uncertainty and implicit result in consumption decision is the source of perceived risk. In order to clarify and evaluate relevant factors, the scale development study has been carried out. With regard to the result, the perceived value scale of smart homes for older adults is made up of ten factors, namely privacy & security risk(7), physical risk(7), technological risk(9), performance risk(7), service risk(9), financial risk(5), psychological risk(7), industry & market risk(6), social support risk(7), policy & law risk(6), in total 70 items. It covers national policy and law, industry and market standard, social support, services responsiveness, technology uncertainty, privacy and security, etc., which contains the potential risk factors from government to society, industry to individual. Our research presents a comprehensive perceived risk measurement scale for the application of relevant smart technologies in dealing with aging challenges and issues in smart home environment which providing a important guidance for controlling, reducing and avoiding relevant risk from an customer-oriented perspective.
- Construction of the technology acceptance model of smart home for the elderly based on perceived value and perceived risk: smart home is an integration system of smart technology which is different from conventional single intelligent technology product or service, so that its acceptance and adoption should be considered in a systematic level rather than perceived usability and perceived ease of use. The ultimate reason for users to accept the relevant products and services of smart home depends on to what kind of extent these technologies can satisfy their value demands as well as reducing and controlling the potential risks. This research breaks through the limitation of conventional technology acceptance model which could not respond to the diverse value needs of customers and ignore the technology uncertainty and negative effects, replaces the variables perceived usefulness and perceived ease of use with perceived value and perceived risk. The whole technology acceptance model is consist of five variables, namely perceived benefit, perceived cost, perceived risk, attitude toward using, behavioral intention to use, among which the perceived benefit and perceived cost is the key component variable of perceived value. Seven hypothesis have been proposed and an empirical study has been conducted through structure equation modeling(SEM) in Amos 25.0. All the hypothesis have been verified and the model fitness reached the threshold.

7.2 Research conclusion

Targeted on the future elderly aged from 45-60 in China, this research develops the perceived value and perceived risk scales of smart homes for future elders by following the standard scale development process. The perceived value scale is consisted of perceived benefit and perceived cost scale, among which the perceived benefit scale contains eight factors with the integration of the PERMA-V wellbeing model, they are independence, healthcare, safety, positive emotion, engagement, relationship, meaning, and achievement, in total 38 measurement items; the perceived cost scale consists of three factors, namely monetary cost, study cost, and space cost, in total 15 items. And the perceived risk scale is made up of ten factors, namely privacy & security risk, physical risk, technological risk, performance risk, service risk, financial risk, psychological risk, industry & market risk, social support risk, policy & law risk, in total 70 items. The combination of these two scales could comprehensively evaluate the elderly's perception of smart homes from the value creation and risk avoidance perspective. Moreover, based on the development of perceived value and perceived risk scales, this study further develops a smart home technology acceptance model for the elderly by using perceived value and perceived risk as the core variables through structural equation modeling. The result shows that the perceived benefit has a significantly positive effect on the attitude of future elders toward smart home using, which will further affect their behavioral intention to use. In contrast, the perceived cost and perceived risk exert a mainly negative effect in the model. Thus, maximizing the perceived benefit in the eight dimensions mentioned above, as well as controlling, reducing, or eliminating perceived risk and perceived cost is the core principle to improve the acceptance and adoption of smart homes for future elders.

7.2.1 Maximize perceived benefit

For the Technology Acceptance Model verified in this research, perceived benefit is the core positive variable of perceived value that ultimately promotes attitude toward using and behavioral intention to use. Therefore, to increase the acceptance of smart home technology for the elderly, one of the most important principles should be maximizing perceived benefit. The perceived benefit in this study takes the PERMA-V wellbeing model as theory basis, and are further divided into eight dimensions, namely, "Independence", "Healthcare", "Safety", "Positive emotion", "Engagement", "Relationship", "Meaning", "Achievement". To maximize perceived benefit, that is, to maximize the omni-directional well-being of the elderly in the smart home environment, which also means to improve the product function and service ability of the smart homes system in these eight dimensions and ensure the relevant quality.

- Independence: The benefit of "independence" contains five items, means that smart homes should bring efficiency and convenience to healthy or mildly disabled elders through smart products and services to help them get rid of dependence on others, achieve self-reliance, self-management, self-care, improve daily life efficiency and provide the help with their weaken ability. It mainly reflected in the home smart technology to meet the basic needs of the elderly, including clothing, eating, housing, moving, and using, such as the automatic control of home appliances, online shopping, take-out foods, taxi calls, picking up express delivery, washing clothes, housekeeping services, etc.
- Healthcare: The benefit of "healthcare" contains five items, means that smart homes should help the elderly realize the management, prevention, treatment and rehabilitation of healthy problems and diseases in home environment to live a healthy lifestyle through smart products and services. It mainly includes the detection and management of physical health through smart medical equipment, online medical consultation, telemedicine, embedded fitness equipment, rehabilitation training equipment, etc.
- Safety: The benefit of "safety" contains five items, means that smart homes should ensure the physical safety, environmental safety, and property safety of the elderly through smart

products and services. Among them, the physical safety of the elderly mainly reflects by the emergency detection and responses, such as sudden heart attacks, falls, etc. Property safety is mainly reflected from the anti-theft monitoring system through smart doors, windows, cameras, etc. Environmental safety is mainly reflected by the monitor of air, water, electricity, fire, etc. in the home environment to prevent accidents such as gas leak and fire disaster.

- Positive emotion: The benefit of "positive emotion" contains seven items, means that smart homes should help the elderly maintain good emotions status through smart products and services, making them feel comfortable, relax, calm, joyful, delighted, excited, loved, and get rid of negative emotions such as loneliness or depression. It mainly includes two aspects. On the one hand, smart home could provide smart home theater, smart game equipment, smart party system, etc. to enable the elderly to engage in different entertainment and social activities, such as listening to music and radio, watching TV series, watching movies, playing chess and card games, family gatherings, etc. On the other hand, smart home could integrate lighting systems, temperature and humidity control systems, door and window systems, etc. to regulate the lighting, temperature, and humidity control to create a comfortable living environment for the elderly.
- Engagement: The benefit of "engagement" contains five items, means that smart homes should help the elderly to engage in activities related to their hobbies and competence in home life through smart products and services. The elderly could enter a state of "heart flow", forgetting time and space, and feel unparalleled happiness from the things they are engaged in. The shaping of engagement mainly includes intelligent information system, intelligent education system, intelligent interest assistance system, etc., to help the elderly master, learn and engage in knowledge and activities that they are interested in.
- Relationship: The benefit of "relationship" contains five items, means that smart homes should help the elderly develop and strengthen their interpersonal bond with the outside world and promote their social interaction through smart products and services. The main objects include their relatives, friends, families, children, couple, pets, related organizations and institutions. Moreover, it can also include the enhancement of the belief or religious connection of the elderly, the development of social companion robots based on artificial intelligence technology, and even the connection with nature through surroundings or the use of virtual reality to enhance their biophilic experience.
- Meaning: The benefit of "meaning" contains five items, means that smart homes should help the elderly to find the purpose and direction of life, provide opportunity to allow them continue making social contribution or reemployment to realize their value of existence after retirement. For example, using the Internet technology and platform to help them achieve re-employment, do freelance work, create start-ups, join online volunteer community to contribute to society, provide remote peers support, help children take care of grandchildren, master knowledge and skills through online study to complete unfulfilled wishes, etc.
- Achievement: The benefit of "achievement" contains three items, means that smart homes should help the elderly to make progress in life, achieving goals and accomplish what they can do to gain a sense of accomplishment. For smart homes, it can be mainly reflected in the sense of reality achievement and virtual achievement. The sense of reality achievement

includes helping the elderly to be appreciated, concerned, and gain the recognition and respect from others or acquire social status through their hobbies, talents, works, etc. The sense of virtual achievement is mainly reflected in the smart home helping the elderly to get likes, comments, fans, and attention on the Internet platform or social media, even in virtual game system to obtain high rank of game character or virtual gaming wealth, etc.

7.2.2 Reduce the perceived cost

In order to enhance the perceived value of smart homes for the elderly which are reflected in the perceived benefit and perceived cost, according to the technology acceptance model, the perceived cost should be controlled and reduced in these three aspects:

- Monetary cost: The "Monetary cost" contains five items, refers to the money that the elderly need to pay during the purchase, transportation, installation, usage, maintenance process of relevant smart home products and services. To reduce monetary, smart home manufacturers and developers are required to consider the purchasing and payment capabilities of the vast majority of the elderly, reducing product development, transportation, assembly, and maintenance cost as much as possible, providing high quality products and services as well as giving a preferential price.
- Study cost: The "Study cost" contains six items, refers to the time, energy, money, intelligence investment of the elderly to learn the usage and operation of related products, equipment, and service systems. As the elderly getting older, their physical strength and intelligence will decrease which will bring different difficulties for them to accept and reflect new things. Therefore, smart homes for the elderly should take their cognitive characteristics and operation habits into consideration, provide them user-friendly operation methods, deliver information intuitively and directly, avoid redundant and complicated functions, so as to improve the accessibility and user experience to reduce their study cost.
- Space cost: The "Space cost" contains four items, refers to the investment that the elderly need to pay for changing the original arrangement of the living environment, removing and discarding of old products and equipment, redecoration and rearrangement of network layout in order to use smart home products and services. Reducing space cost requires smart home products and services for seniors, maximize the usage of original products and living environment of the elderly, and integrating new products and equipment into their original living environment. For example, installing sensors to make the original home products become intelligent and providing light modification services for interior decoration to avoid large-scale discard and re-decoration.

7.2.3 Control, avoid and eliminate perceived risk

In the Technology Acceptance Model, perceived risk includes ten dimensions, namely privacy & security risk, physical risk, technological risk, performance risk, service risk, financial risk, psychological risk, industry & market risk, social support risk, and policy & law risk. The sources of perceived risk in smart homes for the elderly are multi-level and multi-faceted, including the physical and psychological characteristics of users themselves, technical and service issues of products and systems, industry norms and market immaturity, social support systems, government and national laws and regulations, etc., Among them, some can be controlled, some can be avoided, and some can be eliminated. Essentially, perceived risk contains multi-level issues ranging from individuals, enterprises, industries, society to the government. Therefore, the control, reduction and elimination of related risk requires the cooperation and strength from all different levels and fields.

- Privacy & Security risk: The "Privacy & Security risk" contains seven items, means that smart homes should try to remove the elderly's feeling of surveillance, protect their privacy and security of daily life activities, sensitive personal health information data, ownership of their personal data and information, take actions to avoid possible leakage or abuse of users' personal information and data due to system running or security issues in the process of monitoring user activities, health status and home environment.
- Physical risk: The "Physical risk" contains seven items, means that there are potential personal safety hazards and accident brought by smart home systems for the eldelry during the usage process. It is mainly reflected in possible theft, robbery, blackmail and extortion, incorrect or untimely feedback of emergency, accidental injuries caused by equipment physical materials and shapes, invisible health problems caused by electromagnetic radiation. Emphasis and attention should be give to these aspects to protect the elderly's physical health and safety.
- Technological risk: The " Technological risk" contains nine items, refers to the risk which bringing by the immaturity, instability, inflexibility and incompatibility of smart home technology. It is mainly reflected in the low accuracy to recognize and conduct user commands, low system stability, system failures, false alarms, low expansion capability, incompatibility between different products and operating systems, poor data management and treatment ability. The smart home industry should engage in developing and optimizing the smart technology continuously to remove and reduce the technological risk for the elderly.
- Performance risk: The "Performance risk" contains seven items, mainly reflected in the unitary and poor usability, obstruction or impediment devices, aesthetic incongruence with the home environment, low accessibility and unfriendly operation, interference with daily activities. Reducing the performance risk means that the function design, appearance design, interaction design, user experience design, etc. of the smart home system should fully consider the actual needs, operating habits, life routine, individual feelings of the elderly users to provide them user-friendly operation experience.
- Service risk: The "Service risk" contains nine items, means that smart homes for the elderly should provide high service reliability, timely response, enough quality assurance, consistency commercial promise, professional and competent service staffs (Good manner, neat and clean, empathy) for the elderly to meet the elderly's demand and present high service quality.
- Financial risk: The "Financial risk" contains give items, refers to the pressure and uncertainty that users feel for their financial cost during the process of purchasing, using, and maintaining smart home products and services. It is mainly reflected in the relevant products and services are beyond the affordability of the elders, there is non-essential financial expenditure, the money spent doesn't deserve its value, etc. Thus, make the price of smart homes meet the affordability of the majority of aging population and provide them with cost-effective products and services are important and necessary.

- Psychological risk: The "Psychological risk" contains seven items, refers to the pressure of external opinions and internal psychological barriers that users feel during the process of purchasing and using the smart home system. It is mainly reflected in the blame and incomprehension from important persons, unhealthy reliance on automation technology and loss of autonomy, persistent reminder about self-frailty, etc. Thus, the design and development of smart homes should fully consider the psychological characteristics of the elderly and give emphasis to avoiding relevant psychological problems and embarrassment.
- Industry & Market risk: The "Industry and market risk" contains five items, refers to the risk of immature and irregular market and industry development of smart homes for the elderly. It is mainly reflected in the market penetrations stays low and are far from mass adoption, no consistency industry standardization and regulation, no eligibility criteria about the products and services quality, the compatibility of different brands and products is poor, etc. Thus, actions should be taken in the industry and market level to control and reduce relevant risks, such as announce consistency industry standardization and regulation.
- Social support risk: The "Social support risk" contains seven items, mainly exists in the situation that the implementation of smart home products and systems need relevant social resources and forces, such as family support, peer support, community support, neighborhood assistance, institutional assistance, telemedicine services, emergency response etc., The lack of these kinds of support will bring relevant social support risk. Thus, the formation of a social support network for the elderly to support their daily life, healthcare and wellbeing should be given attention and emphasis.
- Policy & law risk: The "Policy & law risk" contains six items, means that the government or relevant public department and authorities should promulgate and issue effective policies and laws to regulate the smart home industry and provide guarantees for serving consumers. It is mainly reflected in the construction of legal framework, standards and guidance as well as mature policy & law conduction and supervision environment.

7.3 Research suggestions and advice

The maturity and development of an emerging technology is inseparable from the support and maturity of the macro and micro level conditions. The following give an discussion about the suggestions and advice of the development of smart homes for the elderly from five different levels, namely user level, enterprise level, industry level, society level, and government level.

7.3.1 User level

- **Maintain a positive attitude toward aging.** Attitude and mentality are the manifestation of a personal spirit state, which will have an important impact on ones behavior pattern. Different attitude will lead to different ways of living, depend on it, the quality of life will be vastly different. Therefore, a pleasure lifestyle and happiness stems from the elderly's own attitude and subjective initiative. The older adults should cultivate a positive attitude, maintain childlike innocence, inspire enthusiasm and initiative in life, set new goals and the pursuit after retirement, and fulfill their inner world, to realize active and healthy aging.

- **Improve information literacy and embrace smart technology.** The development of information technology is an irreversible trend in human society. In the future, people who are not proficient in using smart products will gradually lag behind and lose connection with the era. The elderly group should jump out of their own inherent living habits and comfortable zone, improve their own Internet literacy, actively integrate with the intelligent society, and enjoy the speed and convenience brought by information communication technology. It should not only be the technology adapting to users, people should also actively adapt to technology and keep up with the society development.
- **Explore new possibility of life.** The application of intelligent technology is only a tool that serves the comprehensive development and all-around happiness of people. In the future, smart homes will bring unlimited possibilities to the home life of the elderly. The elderly should try to live a better life and create more possibilities for themselves with the help of intelligent technology when faced with the weakening of their physical and psychological abilities.

7.3.2 Enterprise level

- **Identify the user's core value demands**: The current smart home industry is still in its initial development stage. Although the industry is novel and fashionable, the majority of the products are temporarily limited to the control and automation of home appliances which makes it seems unnecessary and dispensable. At the same time, a plenty of smart home products and services for the elderly have not take their typical characteristics into consideration and lack the insight of their core value demand which may usually concentrate on the healthcare and surveillance aspects. Thus, the future development of smart homes for the elderly should jump out of the conventional shackles and limitation to create a smart home with full sense of happiness for the elderly both physically, psychologically and cognitively.
- **Optimize user experience:** For the existing products and services of smart homes, they usually fail to take the physical, psychological and cognitive characteristics of the elderly into consideration. System accessibility is poor, functions are redundancy, the interface and operation is complex, design and decoration do not cater to the preference of the elderly, etc. Thus, in order to provide a user-friendly interaction between the products and the seniors, the optimization of the user experience of relevant products and services that fully considering the features and habits of the aging is urgent and necessary.
- **Advance digital and artificial intelligence technology:** Nowadays, the smart homes for the elderly still have many technological bottlenecks and challenges which restrict the development of related products and the improvement of its service quality, such as low accuracy, instability and low compatibility of different devices and systems, poor data treatment and management ability, lack of data for training the system to give active and intelligent response to individual needs, etc. The advancement of relevant digital and artificial intelligence technology is still the foundation of providing pleasure products and services for the elderly so that the research and development of technology is the crucial aspect that companies should emphasize for a long time.

- **Improve service quality**: The particular characteristics of the elderly determines the complexity of their service needs and puts forward higher requirements for the service quality of the corresponding system and service providers. Enterprises should strengthen the quality control of related products and systems, give timely responses, improve service reliability and provide adequate service guarantees for the elderly. Moreover, collecting timely user feedback to continuously optimize service quality and gain the service satisfaction of the senior group.
- **Emphasize privacy and security issues**: The smart home system for the elderly should help users get rid of the sense of being monitored as much as possible, protect the privacy of users, evaluate the privacy of users, and allow users to have more autonomous control over their own data. At the same time, the data information of related products is a key guarantee for customer privacy in terms of technical application and security protection. Therefore, companies should also enhance the security protection of related systems in terms of data security and privacy.

7.3.3 Industry level

- **Establish industry standardization:** At present, in addition to famous IT giants, there are numerous enterprises and business groups involved in the smart home industry which presents a multi-domain and mixed commercial background. This kind of phenomenon result in the diversity of different technology standards which make the versatility and compatibility between different products and systems are extremely poor. If the elderly want to enjoy different products and services, they need to install and download various products and software for cross-platform operation, which is really complicated and inefficient. If a consistency industry standard is established for smart home products for the elderly, it will greatly improve the versatility and richness of products and services and reduce the elders' usage costs.
- **Strengthen the construction of service teams**: The current pension industry is facing a serious shortage of human labor and resources. This phenomenon will be increasing serious in the future as the degree of aging further intensifies. The realization of a independent, healthy, safe and happy lifestyle with dignity for the elderly in their old stage requires not only the support of their families, friends, community, society and the public policies, but also a service team with professional and competent working ability. Therefore, the construction of related service teams, the cultivation and training of service staffs, the qualification certification system for service talents are also very important and necessary.

7.3.4 Society level

- **Promote public education:** Many elderly people have a sense of resistance and unfamiliarity with the operation and use of smart technology. Related social institutions or service communities for the elderly can provide them with training courses, free teaching, etc to enhance the elderly’s perception and understanding of intelligent technology and products. In this this, their ability to use and operate related products and service could be improved and their survival capability in this digital era can be strengthened.

- **Build social support network:** The smart home for the elderly is a comprehensive product and service system integration. The implementation and delivery of various elderly services requires the support of different groups in society. Thus, forming a huge social support network, such as social welfare institutions and organizations, community groups, family members, relatives, friends, peers, neighbors, healthcare workers, medical experts, nursing staffs, nutritionists, etc. is very important and necessary for the realization of a pleasure life and comprehensive wellbeing for the elderly.

7.3.5 Government level

- **Provide policy guidance and support**: The development of the smart home industry for the elderly is still in its infancy stage. There is a serious absence of policy guidance and support for the future development direction, industry rules and regulations, technological structures, service standards, etc. Thus, government should pay attention and promulgate relevant policies and work plans to guide the rapid and healthy development of the smart home industry for the elderly to facing with the aging challenges.
- **Release laws for the rights protection.** With the increase of age, the elderly are at a disadvantage in the consumption field because of their decline ability. In this regard, the government departments should release law to standardize elderly-related industries and strengthen legal supervision to regulate the unhealthy trends and illegal phenomena in the smart home industry for the elderly. At the same time, the government should issue relevant laws to provide them with corresponding legal support and legal protection in case of the occurrence of their personal and property loss due to the problems in smart home technology and system, such as the privacy and security issues.

7.4 Research limitation and future study

7.4.1 Limitations of investigation methods

This study collected questionnaires through the Chinese Internet questionnaire platform, Wenjuanxing. The scales and model development did not generate from the real smart home products and systems evaluation. This is because the scale items and model developed in this research is future-targeted which could not get real smart homes samples to conduct the investigation. On the one hand, it is limited by the current development of smart technology. On the other hand, the current elderly users have not cultivated the corresponding market consumption habits for smart homes. With the change of time, the consumption concept of the elderly will be different, and the technology, appearance, and usage context of the product will also be changed and advanced, but no matter how the science and technology develop, the pursuit of wellbeing and happiness stays an eternal theme of mankind. Thus, the core value of technology that it can bring to people and customers will not change. Therefore, the results of this research point out an overall direction for the future development of the smart home industry for the elderly which is toward the construction of all-around happiness. In the future, when conditions permit and mature, the author hopes that the value of the smart home technology mentioned in this research can be realized in a substantive way, and further user evaluation and testing could be carried out based on it.

7.4.2 Limitations of the research population

The data collection in this study is through online questionnaire. That means the responses gotten in this study are from the users who already have strong internet uses basis and shares relative high acceptance of Internet-related smart technologies. Taking this into consideration, the users who still stay low adoption about digital technology is not included in this study. On one hand, this is not a big problem, because if the users are not familiar with internet use, there is no need to mention the adoption of advanced technology products and systems like smart home. On the other hand, it also indicates that the volume of the questionnaires and data collection of this study is still not particularly large which have not included all the different types of potential users. Thus, in the future, the author will further expand the sample size of the data collection to enhance the universality and credibility of the conclusions.

7.4.3 Limitations of analysis content

The main purpose of this research is the development of scales and technology acceptance model validation, which has not considered the impact of demographic variables on the perceived value and perceived risk of smart homes, such as gender, age, occupation, etc. However, people with different characteristics should have different perceived value and perceived risk as well as acceptance of smart homes. Thus, this research did not further explore the content in this aspect. In the future, the author will further explore the differences in the value demands, risk perception, and technology acceptance of elderly people with different characteristics toward smart homes.

7.4.4 Limitations of scale & model examination

This study focuses on the scale development and model generation of smart homes for future elderly. In the future, the author would like to apply the perceived value scale, perceived risk scale and technology acceptance model in the smart homes industry to test the effects how they provide guidance and reference for relevant designers and enterprise practitioners during the smart homes products and services discover, define, develop and delivery process. Moreover, it can be given to the users to do evaluation of how the existing smart homes can improve their quality of life and promote their all-around happiness through the application of smart technology which could provide crucial suggestions and advice to help the related enterprises and service providers find their optimization direction and provide more satisfactory living environment for the elderly.

Appendix

Appendix A

Perceived Value Scale of Smart Homes for Future elderly

The following is the main questionnaire the author used for perceived value scale development. It consists of three parts, the demographic part, the perceived benefit measurement part, and the perceived cost measurement part. For each demographic item, the options have been included in the brackets below. All the scale items have been measured on a 5-point Likert scale. There are five answers that can be selected:" 1=Strongly disagree"," 2=Disagree"," 3=Neutral"," 4=Agree", and "5=Strongly Agree". The definition of each dimension has been given in front of their measurement items to help the participants have a better understanding of related statements. What needs to be mentioned is that the description of the concept of smart home has been presented at the beginning of the questionnaire. The related content can be seen as follows:

"Smart homes are human residential platforms using integrated wiring technology, network communication technology, security technology, automatic control technology, audio and video technology to integrate facilities related to home life to build efficient residential environment with a management system for schedule affairs. Based on the Internet of Things technology, a family ecosystem composed of hardware, software, and cloud computing platforms can realize functions such as remote control, the interconnection between different devices, and self-learning of intelligent systems, etc. Through the collection and analysis of user behavior data to provide users with personalized services, improve home safety, convenience, comfort, and artistry, and even realize an environmentally friendly and energy-saving living space. It is the embodiment of the Internet of Things which can connect various devices and provide home appliance control, lighting control, indoor and outdoor remote control, anti-theft alarm, environmental monitoring, HVAC control, infrared forwarding, and programmable timing control, etc. Compared with an ordinary home, smart home not only has traditional living functions, can provide a comfortable, safe, high-grade, and pleasant living space, but also can transform the interaction between users and systems from the original passive mechanism to active intelligent response, provides a full range of information exchange to enable the home environment to maintain smooth communication with the external world which can significantly improve the users' quality of life.

Imagine that in the next five, ten, twenty years or several decades, when you become old, at that time, the Internet and artificial intelligence technology are highly developed, our home environment is embedded with diverse smart products with abundant functions and service systems to improve the quality of life of the elderly and promote their all-around happiness in home environment. Under this assumption, please rate the acceptance of the following statements, where "1" is "strongly disagree", "2" is "disagree", "3" is "general", and "4" is "agree", "5" means "strongly agree".

Demographics

Gender (Male, Female), Age (45-50, 51-55, 56-60), Education Level (<High school, High school, Associate, Bachelor, Master, Doctor), Marital status (Single, Married, Divorced, Widowed), Monthly Income (<1000, 1000-3000, 3000-5000, 5000-7000, 7000-10000, 10000+), Occupation (Teachers, Civil Servants, IT company staff, Non-IT company staff, Private entrepreneur, Freelancer, Worker, Farmer, Others)

Measurement- Perceived Benefit

Independence (IND)

The benefit of "independence" means that smart homes can bring efficiency and convenience to healthy or mildly disabled elders through smart products and services to help them get rid of dependence on others, achieve self-reliance, self-management, self-care, and live with dignity. It mainly reflected in the smart home technology to meet the basic needs of the elderly, including clothing, eating, housing, moving, and using, such as the automatic control of home appliances, online shopping, take-out foods, taxi calls, picking up express delivery, washing clothes, housekeeping services, etc.

- When I am old, smart homes can help me realize self-reliance.
- When I am old, smart homes can help me realize self-care.
- When I am old, smart homes can help me realize self-management.
- When I am old, smart homes can help me improve daily life efficiency.
- When I am old, smart homes can make my life more convenient.
- When I am old, smart homes can provide products and services to help with my weaken ability.

Healthcare (HEA)

The benefit of "healthcare" means that smart homes can help the elderly realize the management, prevention, treatment, and rehabilitation of health problems and diseases in the home environment to live a healthy lifestyle through smart products and services. It mainly includes the detection and management of physical health through smart medical equipment, online medical consultation, telemedicine, embedded fitness equipment, rehabilitation training equipment, etc.

- When I am old, smart homes can detect my health data and give timely feedback to me.
- When I am old, smart homes can let me exercise at home and realize disease prevention.
- When I am old, smart homes can provide teleconsultation for me.
- When I am old, smart homes can provide telemedicine services for me.
- When I am old, smart homes can provide telecare for me when I need it.
- When I am old, smart homes can help me with rehabilitation if I got serious disease or finished surgery.
- When I am old, smart homes can help me keep in contact with my medical administration.

Safety (SAF)

The benefit of "safety" means that smart homes can ensure the physical safety, social safety, environmental safety, and property safety of the elderly through smart products and services. Among them, the physical safety of the elderly mainly reflects by emergency detection and responses, such as sudden heart attacks, falls, etc. Social safety means that the elderly can always get support and help from relevant social forces when they need it. Property safety is mainly reflected from the anti-theft monitoring system through smart doors, windows, cameras, etc. Environmental safety is mainly reflected by the monitor of air, water, electricity, fire, etc., in the home environment to prevent accidents such as gas leaks and fire disasters.

- When I am old, smart homes can ensure my life's safety.
- When I am old, smart homes can ensure my social safety.
- When I am old, smart homes can ensure my environmental safety.
- When I am old, smart homes can ensure my property safety.
- When I am old, smart homes can provide emergency responses if I got any accident at home.

Positive Emotion (PE)

The benefit of "positive emotion" means that smart homes can help the elderly maintain good emotional status through smart products and services, making them feel comfortable, relaxed, enjoyable, excited, loved, and get rid of negative emotions such as loneliness or depression. It mainly includes two aspects. On the one hand, smart home could provide smart home theater, smart game equipment, smart party system, etc. to enable the elderly to engage in different entertainment and social activities, such as listening to music and radio, watching TV series, watching movies, playing chess and card games, family gatherings, etc. On the other hand, smart home could integrate lighting systems, temperature and humidity control systems, door and window systems, etc., to regulate the lighting, temperature, and humidity control to create a comfortable living environment for the elderly.

- When I am old, smart homes can enable me to feel comfortable.
- When I am old, smart homes can enable me to feel relaxed.
- When I am old, smart homes can enable me to feel calm.
- When I am old, smart homes can enable me to feel joyful.
- When I am old, smart homes can enable me to feel delighted.
- When I am old, smart homes can enable me to feel excited.
- When I am old, smart homes can enable me to feel I am loved.

Engagement (ENG)

The benefit of "engagement" means that smart homes can help the elderly to engage in activities related to their hobbies and competence in home life through smart products and services. The elderly could enter a state of "heart flow", forgetting time and space, and feel unparalleled happiness from the things they are engaged in. The shaping of engagement mainly includes intelligent information systems, intelligent education systems, intelligent interest assistance systems, etc., to help the elderly master, learn and engage in knowledge and activities that they are interested in.

- When I am old, smart homes can provide me with competent tasks.
- When I am old, smart homes can provide me with the support of my interest development.
- When I am old, smart homes can enable me to learn knowledge and skills which I want to learn.
- When I am old, smart homes can enable me to get the state of absorption and concentration.
- When I am old, smart homes can enable me to lose track of time and space while doing something I enjoy.

Relationship (REL)

The benefit of "relationship" means that smart homes can help the elderly develop and strengthen their interpersonal bond with the outside world and promote their social interaction through smart products and services. The main objects include their relatives, friends, families, children, couples, pets, related organizations, and institutions. Moreover, it can also include the enhancement of the belief or religious connection of the elderly, the development of social companion robots based on artificial intelligence technology, and even the connection with nature through surroundings or the use of virtual reality to enhance their experience about the virtual nature.

- When I am old, smart homes can provide the functions and services to increase family interaction.
- When I am old, smart homes can strengthen my social life and cultivate connections to others.
- When I am old, smart homes can provide me with companionship.
- When I am old, smart homes can provide the functions and services to help me strengthen the connection with my belief.
- When I am old, smart homes can provide the functions and services to help me feed my pets.
- When I am old, smart homes can provide the functions and services to strengthen my biophilic experience and the connection with nature.
- When I am old, smart homes can provide the functions and services to strengthen my friendship.

Meaning (MEA)

The benefit of "meaning" means that smart homes can help the elderly to find the purpose and direction of life, provide the opportunity to allow them to continue making social contributions or reemployment to realize their value of existence after retirement. For example, using the Internet technology and platform to help them achieve re-employment, do freelance work, create start-ups, join online volunteer community to contribute to society, provide remote peers support, help children take care of grandchildren, master knowledge and skills through online study to complete unfulfilled wishes, etc.

- When I am old, smart homes can make me feel I have a sense of direction and purpose in my life.
- When I am old, smart homes can help me to do family responsibilities.
- When I am old, smart homes can enable me to make social contributions via technology and the Internet.
- When I am old, smart homes can help me do some things which I could not do when I am young via smart technology.
- When I am old, smart homes can enable me to do re-employment via technology and the Internet.

Achievement (ACH)

The benefit of "achievement" means that smart homes can help the elderly to accomplish what they can do and gain a sense of accomplishment. For smart homes, it mainly includes the sense of reality achievement and virtual achievement. The sense of reality achievement includes helping the elderly to be appreciated, concerned, and gain recognition and respect from others or acquire social status through their hobbies, talents, works, etc. The sense of virtual achievement is mainly reflected in the smart home helping the elderly to get likes, comments, fans, and attention on the Internet platform or social media, even in the virtual game system to obtain high rank of game character or virtual gaming wealth, etc.

- When I am old, smart homes can help me make progress in life.
- When I am old, smart homes can help me achieve my goals.
- When I am old, smart homes can help me feel good about myself.
- When I am old, smart homes can help me feel confident about myself.
- When I am old, smart homes can help me feel proud of myself.
- When I am old, smart homes can help me have a sense of accomplishment in life.

Measurement-Perceived Cost

Monetary Cost (MON)

The "Monetary cost" refers to the money that the elderly need to pay during the purchase, transportation, installation, usage, maintenance process of relevant smart home products and services.

- If I want to use smart homes when I am old, I need to buy related products and equipment.
- If I want to use smart homes when I am old, I need to pay for related services.
- If I want to use smart homes when I am old, I need to pay for installation fee.
- If I want to use smart homes when I am old, I need to pay for maintenance fee.
- If I want to use smart homes when I am old, I need to pay for Transportation fee.

Study Cost (STU)

The "Study cost" refers to the time, energy, money, intelligence investment of the elderly to learn the usage and operation of related products, equipment, and service systems.

- If I want to use smart homes when I am old, I need to spend time learning how to use it.
- If I want to use smart homes when I am old, I need to spend money learning how to use it.

- If I want to use smart homes when I am old, I need to spend energy learning how to use it.
- If I want to use smart homes when I am old, I need to seek for others help to teach me how to use it.
- If I want to use smart homes when I am old, I need to learn related legislation and regulations.
- If I want to use smart homes when I am old, I need to learn related industry standardization.

Space Cost (SPA)

The "Space cost" refers to the investment that the elderly need to pay for changing the original arrangement of the living environment, removing and discarding old products and equipment, redecoration, and rearrangement of network layout in order to use smart home products and services.

- If I want to use smart homes when I am old, I need to change the arrangement of my house.
- If I want to use smart homes when I am old, I need to change the decoration of my house.
- If I want to use smart homes when I am old, I need to remove the old equipment and furniture in my house.
- If I want to use smart homes when I am old, I need to rearrange the network layout of my house.

Appendix B

Perceived Risk Scale of Smart Homes for Future elderly

The following is the main questionnaire the author used for perceived risk scale development. It consists of two parts, the demographic part, and the perceived risk measurement part. For each demographic item, the options have been included in the brackets below. All the scale items have been measured on 5-point Likert scale. There are five answers can be selected:" 1=Strongly disagree"," 2=Disagree"," 3=Neutral"," 4=Agree" and "5=Strongly Agree". The definition of each dimension has been given in front of their measurement items to help the participants have a better understanding of related statements. What needs to be mentioned is that, the description of the concept of smart home has been presented at the beginning of the questionnaire. The related content could be seen as follows:

"Smart homes are human residential platforms using integrated wiring technology, network communication technology, security technology, automatic control technology, audio and video technology to integrate facilities related to home life to build efficient residential environment with a management system for schedule affairs. Based on the Internet of Things technology, a family ecosystem composed of hardware, software, and cloud computing platforms can realize functions such as remote control, the interconnection between different devices, and self-learning of intelligent systems, etc. Through the collection and analysis of user behavior data to provide users with personalized services, improve home safety, convenience, comfort, and artistry, and even realize an environmentally friendly and energy-saving living space. It is the embodiment of the Internet of Things which can connect various devices and provide home appliance control, lighting control, indoor and outdoor remote control, anti-theft alarm, environmental monitoring, HVAC control, infrared forwarding, and programmable timing control, etc. Compared with an ordinary home, smart home not only has traditional living functions, can provide a comfortable, safe, high-grade, and pleasant living space, but also can transform the interaction between users and systems from the original passive mechanism to active intelligent response, provides a full range of information exchange to enable the home environment to maintain smooth communication with the external world which can significantly improve the users' quality of life.

Imagine that in the next five, ten, twenty years or several decades, when you become old, at that time, the Internet and artificial intelligence technology are highly developed, our home environment is embedded with diverse smart products with abundant functions and service systems to improve the quality of life of the elderly and promote their all-around happiness in home environment. At the same time, the risks brought by smart technologies and the external world are also widespread and exist. Under this assumption, please rate the acceptance of the following statements, where "1" is "strongly disagree", "2" is "disagree", "3" is "general", and "4" is "agree", "5" means "strongly agree".

Demographics

Gender (Male, Female), Age (45-50, 51-55, 56-60), Education Level (<High school, High school, Associate, Bachelor, Master, Doctor), Marital status (Single, Married, Divorced, Widowed), Monthly Income (<1000, 1000-3000, 3000-5000, 5000-7000, 7000-10000, 10000+), Occupation (Teachers, Civil Servants, IT company staff, Non-IT company staff, Private entrepreneur, Freelancer, Worker, Farmer, Others)

Measurement-Perceived Risk

Privacy & Security Risk (PS)

The" Privacy & Security risk "refers to the non-autonomy, possible leakage or abuse of users' personal information and data due to system running or security issues in the process of monitoring user activities, health status, and home environment.

- I don't like the feeling of surveillance.
- I don't like to share my personal daily life activities with others.

- I don't like to share my sensitive personal health information data with my important person.
- I am worried about the ownership of my personal data and information.
- I am worried that my personal data and information may be misused without my permission.
- I am worried about the unauthorized access to my personal data and information and for what purpose it may be used.
- I am worried that the smart homes system has loopholes and might be attacked by hacker.

Physical Risk (PHY)

The" Physical risk "refers to the potential personal safety hazards and accidents brought by smart home systems. It is mainly reflected in possible theft, robbery, blackmail and extortion, incorrect or untimely feedback of emergency, accidental injuries caused by equipment physical materials and shapes, invisible health problems caused by electromagnetic radiation, etc.

- I am worried that using smart homes will increase the risk of theft.
- I am worried that using smart homes will increase the risk of robbery.
- I am worried that using smart homes will increase the risk of blackmail and extortion.
- I am worried that some devices or equipment may be lack of reliable physical quality and hurt me.
- I am worried that the smart homes may provide me with wrong information or conduct wrong commands and harm me.
- I am worried that when I encounter emergency problems, the smart homes could not provide timely responses and help.
- I am worried that the usage and radiation of smart homes will bring unexpected health problems.

Technological Risk (TECH)

The "Technological risk" refers to the risk brought by the immaturity, instability, inflexibility, and incompatibility of smart home technology. It is mainly reflected in the low accuracy to recognize and conduct user commands, low system stability, system failures, false alarms, low expansion capability, incompatibility between different products and operating systems, poor data management and treatment ability, etc.

- I am worried that the smart homes system could not identify or conduct my command accurately.
- I am worried that the smart homes may have malfunctions or suboptimal performance.
- I am worried that the smart homes may lack of reliability in the system.
- I am worried that the smart homes will deliver wrong messages to related people or service staff.
- I am worried that the smart homes devices and systems may have low expansion capability.
- I am worried that the smart homes may lack of interoperability among different devices and heterogeneous systems.
- I am worried that the smart homes technology update too fast and old-fashioned system may have low stability.
- I am worried that the smart homes may have inflexibility problems.
- I am worried that the smart homes should conduct continuous machine learning and may lack of data to organize programme for me.
- I am worried that the data management (record, storage, handling capability, and compression) techniques are immature.
- I am worried that the smart homes lack continuous monitoring of elderly people.
- I am worried that the smart homes may give a false alarm.

Performance Risk (PER)

The" Performance risk" refers to the function design, appearance design, interaction design, user experience design, etc., of the smart home system, do not fully consider the actual needs, operating habits, life routine, individual feelings of the elderly users. It is mainly reflected in the unitary and poor usability, obstruction or impediment devices, aesthetic incongruence with the home environment, low accessibility and unfriendly operation, interference with daily activities, etc.

- I am worried that the smart homes function is too unitary and may have poor usability.
- I am worried that the smart homes devices are obstruction or impediment in space and make me feel uncomfortable at home.
- I am worried that the smart homes devices are aesthetic incongruence which cannot integrate with my house environment.
- I am worried that the smart homes devices and systems have low accessibility and are hard to use.
- I am worried that the smart homes interface and interaction is lack of user-friendliness for elderly people.
- I am worried that the smart homes function could not meet my needs and demand as time goes by.
- I am worried that the smart homes have interference with my daily activities.
- I am worried that the smart homes may disrupt my daily routines.

Service Risk (SER)

The "Service risk" refers to the smart home services that cannot meet the elderly's demand and present low service quality. It is mainly reflected in low service reliability, no timely response, no enough quality assurance, no consistent commercial promise, unprofessional and incompetent service staff, etc.

- I am worried that the smart homes services are not reliable.
- I am worried that the smart homes services could not give me timely responses.
- I am worried that the smart homes services do not have assurance.
- I am worried that the smart homes services could not provide consistent services according to their promise.
- I am worried that the smart homes services could not provide suitable and professional services.
- I am worried that the smart homes services could not provide the personalized services I want.
- I am worried that the smart homes services staff could not treat me in a good manner.
- I am worried that the smart homes services staff is in low neatness and cleanness.
- I am worried that the smart homes services staff could not understand my specific needs.

Financial Risk (FIN)

The "Financial risk" refers to the pressure and uncertainty that users feel for their financial cost during the process of purchasing, using, and maintaining smart home products and services. It is mainly reflected in the relevant products and services are beyond the affordability of the elders, there is some non-essential financial expenditure, the money spent doesn't deserve its value, etc.

- I am worried that the cost of smart homes products and services is beyond my affordability.
- I am worried that the money I pay for smart homes doesn't deserve its value.
- I am worried that I will spend more money on its affordable services if I use smart homes.
- I am worried that smart homes may bring me some non-essential financial expenditure.
- I am worried that smart homes may increase my financial pressure.

Psychological Risk (PSY)

The "Psychological risk" refers to the pressure of external opinions and internal psychological barriers that users feel during the process of purchasing and using the smart home system. It is mainly reflected in the blame and incomprehension from important persons, unhealthy reliance on automation technology and loss of autonomy, persistent reminder about self-frailty, etc.

- I am worried that my family will blame me for the usage of smart homes.
- I am worried that my friends will think I am strange if I use smart homes.
- I am worried that smart homes may cause embarrassment or stigma when people visit my house.
- I am worried that smart homes devices may be a burden to the people who live with me.
- I am worried that smart homes may replace or diminish my human contact and result in social isolation.
- I am worried that the smart homes will result in my reliance on automation technology and loss of autonomy
- I am worried that the smart homes devices will always be perceived as reinforcing an image of being “old” for myself.

Industry & Market Risk (IM)

The "Industry & market risk" refers to the risk of the immature and irregular market and industry development of smart homes for the elderly. It is mainly reflected in the market penetrations staying low and far from mass adoption, no consistency in industry standardization and regulation, no eligibility criteria about the products and services quality, the compatibility of different brands and products is poor, etc.

- I am worried that there is an absence of a comprehensive market.
- I am worried that there is no consistent standardization and regulation of the smart home industry.
- I am worried that the product update too fast and the products I brought would be obsolete soon.
- I am worried that there are no eligibility criteria for the enterprises and service providers' quality and level.
- I am worried that the compatibility of different brands, systems, devices is terrible.
- I am worried that there is a shortage of service labor in related aging industry.

Social Support Risk (SS)

The "Social support risk" mainly exists in the situation that the implementation of smart home products and systems need relevant social resources and forces, such as family support, peer support, community support, neighborhood assistance, institutional assistance, telemedicine services, emergency response, etc., The lack of these kinds of support will bring relevant social support risk.

- I am worried that if there is no enough support from healthcare providers.
- I am worried that there is no enough support from caregivers.
- I am worried that there is no enough support from medical staff.
- I am worried that there is no enough support from medical experts.
- I am worried that there is no enough support from my family.
- I am worried that there is no enough support from my relatives.
- I am worried that there is no enough support from my friends.
- I am worried that there is no enough support from my neighborhood.
- I am worried that there is no enough support from my community.
- I am worried that there is no enough support from organizations and institutions.

Policy & Law Risk (PL)

The "Policy & law risk" refers to the government or relevant public department and authorities that have not promulgated and issued effective policies and laws to regulate the smart home industry and provide guarantees for serving consumers. It is mainly reflected in the lack of legal framework, standards, and guidance as well as immature policy & law conduction and supervision environment.

- I am worried that there is a lack of policy or legal framework to give the standards and guidance.
- I am worried that there is a lack of policy & law conduct environment.
- I am worried that there is a lack of policy & law supervision environment.
- I am worried that there is a lack of policy & law to provide the right assurance.
- I am worried that there is a lack of legal responsibilities and professional competence of related service providers and caregivers.
- I am worried that there is a lack of legal aid if some accident happened due to the technology or service problems.

Appendix C

Technology Acceptance Model of Smart Homes for Future elders

The following is the main questionnaire the author used for the construction of the technology acceptance model of smart homes for future elderly. The model includes five variables. The perceived benefit and perceived cost could consist of perceived value which used the measurement scale developed in Chapter 4. The perceived risk was measured via the scale developed in Chapter 5. The measurement items of attitude toward using and behavioral intention to use were extracted from existing academic papers. For each demographic item, the options have been included in the brackets below. All the scale items have been measured on 5-point Likert scale. There are five answers that can be selected:" 1=Strongly disagree"," 2=Disagree"," 3=Neutral"," 4=Agree" and "5=Strongly Agree". The definition of all the variables and their dimensions has been given in front of their measurement items to help the participants have a better understanding of related statements. What needs to be mentioned is that the description of the concept of smart home has been presented at the beginning of the questionnaire. The related content can be seen as follows:

"Smart homes are human residential platforms using integrated wiring technology, network communication technology, security technology, automatic control technology, audio and video technology to integrate facilities related to home life to build efficient residential environment with a management system for schedule affairs. Based on the Internet of Things technology, a family ecosystem composed of hardware, software, and cloud computing platforms can realize functions such as remote control, the interconnection between different devices, and self-learning of intelligent systems, etc. Through the collection and analysis of user behavior data to provide users with personalized services, improve home safety, convenience, comfort, and artistry, and even realize an environmentally friendly and energy-saving living space. It is the embodiment of the Internet of Things which can connect various devices and provide home appliance control, lighting control, indoor and outdoor remote control, anti-theft alarm, environmental monitoring, HVAC control, infrared forwarding, and programmable timing control, etc. Compared with an ordinary home, smart home not only has traditional living functions, can provide a comfortable, safe, high-grade, and pleasant living space, but also can transform the interaction between users and systems from the original passive mechanism to active intelligent response, provides a full range of information exchange to enable the home environment to maintain smooth communication with the external world which can significantly improve the users' quality of life.

Imagine that in the next five, ten, twenty years or several decades, when you become old, at that time, the Internet and artificial intelligence technology are highly developed, our home environment is embedded with diverse smart products with abundant functions and service systems to improve the quality of life of the elderly and promote their all-around happiness in home environment. At the same time, the risks brought by smart technologies and the external world are also widespread and exist. Under this assumption, please rate the acceptance of the following statements, where "1" is "strongly disagree", "2" is "disagree", "3" is "general", and "4" is "agree", "5" means "strongly agree".

Demographics

Gender (Male, Female), Age (45-50, 51-55, 56-60), Education Level (<High school, High school, Associate, Bachelor, Master, Doctor), Marital status (Single, Married, Divorced, Widowed), Monthly Income (<1000, 1000-3000, 3000-5000, 5000-7000, 7000-10000, 10000+), Occupation (Teachers, Civil Servants, IT company staff, Non-IT company staff, Private entrepreneur, Freelancer, Worker, Farmer, Others)

Measurement- Perceived Benefit

Independence (IND)

The benefit of "independence" means that smart homes can bring efficiency and convenience to healthy or mildly disabled elders through smart products and services to help them get rid of dependence on others, achieve self-reliance, self-management, self-care, and live with dignity. It mainly reflected in the home smart technology to meet the basic needs of the elderly, including clothing, eating, housing, moving, and using, such as the automatic control of home appliances, online shopping, take-out foods, taxi calls, picking up express delivery, washing clothes, housekeeping services, etc.

- When I am old, smart homes can help me realize self-reliance.
- When I am old, smart homes can help me realize self-care.
- When I am old, smart homes can help me realize self-management.
- When I am old, smart homes can help me improve daily life efficiency.
- When I am old, smart homes can provide products and services to help with my weaken ability.

Healthcare (HEA)

The benefit of "healthcare" means that smart homes can help the elderly realize the management, prevention, treatment, and rehabilitation of health problems and diseases in the home environment to live a healthy lifestyle through smart products and services. It mainly includes the detection and management of physical health through smart medical equipment, online medical consultation, telemedicine, embedded fitness equipment, rehabilitation training equipment, etc.

- When I am old, smart homes can detect my health data and give timely feedback to me.
- When I am old, smart homes can let me exercise at home and realize disease prevention.
- When I am old, smart homes can provide telemedicine services for me.
- When I am old, smart homes can help me with the rehabilitation if I got serious diseases or finished surgery.
- When I am old, smart homes can help me keep in contact with my medical administration.

Safety (SAF)

The benefit of "safety" means that smart homes can ensure the physical safety, social safety, environmental safety, and property safety of the elderly through smart products and services. Among them, the physical safety of the elderly mainly reflects by emergency detection and responses, such as sudden heart attacks, falls, etc. Property safety is mainly reflected from the anti-theft monitoring system through smart doors, windows, cameras, etc. Environmental safety is mainly reflected by the monitor of air, water, electricity, fire, etc., in the home environment to prevent accidents such as gas leaks and fire disasters.

- When I am old, smart homes can ensure my life's safety.
- When I am old, smart homes can ensure my environmental safety.
- When I am old, smart homes can ensure my property safety.

Positive Emotion (PE)

The benefit of "positive emotion" means that smart homes can help the elderly maintain good emotional status through smart products and services, making them feel comfortable, relaxed, enjoyable, excited, loved, and get rid of negative emotions such as loneliness or depression. It mainly includes two aspects. On the one hand, smart home could provide smart home theater, smart game equipment, smart party system, etc. to enable the elderly to engage in different entertainment and social activities, such as listening to music and radio, watching TV series, watching movies, playing chess and card games, family gatherings, etc. On the other hand, smart homes could integrate lighting systems, temperature and humidity control systems, door and window systems, etc., to regulate the lighting, temperature, and humidity control to create a comfortable living environment for the elderly.

- When I am old, smart homes can enable me to feel comfortable.
- When I am old, smart homes can enable me to feel relaxed.
- When I am old, smart homes can enable me to feel calm.

- When I am old, smart homes can enable me to feel joyful.
- When I am old, smart homes can enable me to feel delighted.
- When I am old, smart homes can enable me to feel excited.
- When I am old, smart homes can enable me to feel I am loved.

Engagement (ENG)

The benefit of "engagement" means that smart homes can help the elderly to engage in activities related to their hobbies and competence in home life through smart products and services. The elderly could enter a state of "heart flow", forgetting time and space, and feel unparalleled happiness from their activities. The shaping of engagement mainly includes intelligent information systems, intelligent education systems, intelligent interest assistance systems, etc., to help the elderly master, learn and engage in knowledge and activities that they are interested in.

- When I am old, smart homes can provide me with competent tasks.
- When I am old, smart homes can provide me with the support of my interest development.
- When I am old, smart homes can enable me to learn knowledge and skills which I want to learn.
- When I am old, smart homes can enable me to get the state of absorption and concentration.
- When I am old, smart homes can enable me to lose track of time and space while doing something I enjoy.

Relationship (REL)

The benefit of "relationship" means that smart homes can help the elderly develop and strengthen their interpersonal bond with the outside world and promote their social interaction through smart products and services. The main objects include their relatives, friends, families, children, couples, pets, related organizations, and institutions. Moreover, it can also include the enhancement of the belief or religious connection of the elderly, the development of social companion robots based on artificial intelligence technology, and even the connection with nature through surroundings or the use of virtual reality to enhance their experience about the virtual nature.

- When I am old, smart homes can provide the functions and services to increase family interaction.
- When I am old, smart homes can strengthen my social life and cultivate connections to others.
- When I am old, smart homes can provide me with companionship.
- When I am old, smart homes can provide the functions and services to help me strengthen the connection with my belief.
- When I am old, smart homes can provide the functions and services to strengthen my biophilic experience and the connection with nature.

Meaning (MEA)

The benefit of "meaning" means that smart homes can help the elderly to find the purpose and direction of life, provide opportunities to allow them to continue making social contribution or reemployment to realize their value of existence after retirement. For example, using the Internet technology and platform to help them achieve re-employment, do freelance work, create start-ups, join online volunteer community to contribute to society, provide remote peers support, help children take care of grandchildren, master knowledge and skills through online study to complete unfulfilled wishes, etc.

- When I am old, smart homes can make me feel I have a sense of direction and purpose in my life.
- When I am old, smart homes can help me to do family responsibilities.

- When I am old, smart homes can enable me to make social contributions via technology and the Internet.
- When I am old, smart homes can help me do some things which I could not do when I am young via smart technology.
- When I am old, smart homes can enable me to do re-employment via technology and the Internet.

Achievement (ACH)

The benefit of "achievement" means that smart homes can help the elderly to accomplish what they can do and gain a sense of accomplishment. For smart homes, it mainly includes the sense of reality achievement and virtual achievement. The sense of reality achievement includes helping the elderly be appreciated, concerned, and gain recognition and respect from others or acquire social status through their hobbies, talents, works, etc. The sense of virtual achievement is mainly reflected in the smart home helping the elderly to get likes, comments, fans, and attention on the Internet platform or social media, even in the virtual game system to obtain a high rank of game character or virtual gaming wealth, etc.

- When I am old, smart homes can help me make progress in life.
- When I am old, smart homes can help me achieve my goals.
- When I am old, smart homes can help me have a sense of accomplishment in life.

Measurement-Perceived Cost

Monetary Cost (MON)

The "Monetary cost" refers to the money that the elderly need to pay during the purchase, transportation, installation, usage, maintenance process of relevant smart home products and services.

- If I want to use smart homes when I am old, I need to buy related products and equipment.
- If I want to use smart homes when I am old, I need to pay for related services.
- If I want to use smart homes when I am old, I need to pay for installation fee.
- If I want to use smart homes when I am old, I need to pay for maintenance fee.
- If I want to use smart homes when I am old, I need to pay for transportation fee.

Study Cost (STU)

The "Study cost" refers to the time, energy, money, intelligence investment of the elderly to learn the usage and operation of related products, equipment, and service systems.

- If I want to use smart homes when I am old, I need to spend time learning how to use it.
- If I want to use smart homes when I am old, I need to spend money learning how to use it.
- If I want to use smart homes when I am old, I need to spend energy learning how to use it.
- If I want to use smart homes when I am old, I need to seek others help to teach me how to use it.
- If I want to use smart homes when I am old, I need to learn related legislation and regulations.
- If I want to use smart homes when I am old, I need to learn related industry standardization.

Space Cost (SPA)

The "Space cost" refers to the investment that the elderly need to pay for changing the original arrangement of the living environment, removing and discarding of old products and equipment, redecoration, and rearrangement of network layout in order to use smart home products and services.

- If I want to use smart homes when I am old, I need to change the arrangement of my house.
- If I want to use smart homes when I am old, I need to change the decoration of my house.
- If I want to use smart homes when I am old, I need to remove the old equipment and furniture in my house.
- If I want to use smart homes when I am old, I need to rearrange the network layout of my house.

Measurement-Perceived Risk

Privacy & Security Risk (PS)

The "Privacy & Security risk" refers to the non-autonomy, possible leakage or abuse of users' personal information and data due to system running or security issues in the process of monitoring user activities, health status, and home environment.

- I don't like the feeling of surveillance.
- I don't like to share my personal daily life activities with others.
- I don't like to share my sensitive personal health information data with my important person.
- I am worried about the ownership of my personal data and information.
- I am worried that my personal data and information may be misused without my permission.
- I am worried about the unauthorized access to my personal data and information and for what purpose it may be used.
- I am worried that the smart homes system has loopholes and might be attacked by hacker.

Physical Risk (PHY)

The "Physical risk" refers to the potential personal safety hazards and accidents brought by smart home systems. It is mainly reflected in possible theft, robbery, blackmail and extortion, incorrect or untimely feedback of emergency, accidental injuries caused by equipment physical materials and shapes, invisible health problems caused by electromagnetic radiation, etc.

- I am worried that using smart homes will increase the risk of theft.
- I am worried that using smart homes will increase the risk of robbery.
- I am worried that using smart homes will increase the risk of blackmail and extortion.
- I am worried that some devices or equipment may be lack of reliable physical quality and hurt me.
- I am worried that the smart homes may provide me wrong information or conduct wrong command and bring harm to me.
- I am worried that smart homes could not provide timely responses and help when I encounter emergency problems.
- I am worried that the usage and radiation of smart homes will bring unexpected health problems.

Technological Risk (TECH)

The "Technological risk" refers to the risk brought by the immaturity, instability, inflexibility, and incompatibility of smart home technology. It is mainly reflected in the low accuracy to recognize and conduct user commands, low system stability, system failures, false alarms, low expansion capability, incompatibility between different products and operating systems, poor data management and treatment ability, etc.

- I am worried that the smart homes system could not identify or conduct my command accurately.
- I am worried that the smart homes may have malfunctions or suboptimal performance.
- I am worried that the smart homes may lack of reliability in the system.

- I am worried that the smart homes will deliver wrong messages to related people or service staff.
- I am worried that the smart homes devices and systems may have low expansion capability.
- I am worried that the smart homes may lack of interoperability among different devices and heterogeneous systems.
- I am worried that the smart homes technology update too fast and old-fashioned system may have low stability.
- I am worried that the smart homes should conduct continuous machine learning and may lack of data to organize programme for me.
- I am worried that the data management (record, storage, handling capability, and compression) techniques are immature.

Performance Risk (PER)

The "Performance risk" refers to the function design, appearance design, interaction design, user experience design, etc., of the smart home system, which does not fully consider the actual needs, operating habits, life routine, individual feelings of the elderly users. It is mainly reflected in the unitary and poor usability, obstruction or impediment devices, aesthetic incongruence with the home environment, low accessibility and unfriendly operation, interference with daily activities, etc.

- I am worried that the smart homes function is too unitary and may have poor usability.
- I am worried that the smart homes devices are obstruction or impediment in space and make me feel uncomfortable at home.
- I am worried that the smart homes devices are aesthetic incongruence which cannot integrate with my house environment.
- I am worried that the smart homes devices and systems have low accessibility and are hard to use.
- I am worried that the smart homes interface and interaction is lack of user-friendliness for elderly people.
- I am worried that the smart homes have interference with my daily activities.

Service Risk (SER)

The "Service risk" refers to the smart home services cannot meet the elderly's demand and present low service quality. It is mainly reflected in low service reliability, no timely response, no enough quality assurance, no consistent commercial promise, unprofessional and incompetent service staff, etc.

- I am worried that the smart homes services are not reliable.
- I am worried that the smart homes services could not give me timely responses.
- I am worried that the smart homes services do not have assurance.
- I am worried that the smart homes services could not provide consistent services according to their promise.
- I am worried that the smart homes services could not provide suitable and professional services.
- I am worried that the smart homes services could not provide the personalized services I want.
- I am worried that the smart homes services staff could not treat me in a good manner.
- I am worried that the smart homes services staff is in low neatness and cleanness.
- I am worried that the smart homes services staff could not understand my specific needs.

Financial Risk (FIN)

The "Financial risk" refers to the pressure and uncertainty that users feel for their financial cost during the process of purchasing, using, and maintaining smart home products and services. It is mainly reflected in the relevant products and services are beyond the affordability of the elders, there is some non-essential financial expenditure, the money spent doesn't deserve its value, etc.

- I am worried that the cost of smart homes products and services is beyond my affordability.
- I am worried that the money I pay for smart homes doesn't deserve its value.
- I am worried that I will spend more money on its affordable services if I use smart homes.
- I am worried that smart homes may bring me some non-essential financial expenditure.
- I am worried that smart homes may increase my financial pressure.

Psychological Risk (PSY)

The "Psychological risk" refers to the pressure of external opinions and internal psychological barriers that users feel during the process of purchasing and using the smart home system. It is mainly reflected in the blame and incomprehension from important persons, unhealthy reliance on automation technology and loss of autonomy, persistent reminder about self-frailty, etc.

- I am worried that my family will blame me for the usage of smart homes.
- I am worried that my friends will think I am strange if I use smart homes.
- I am worried that smart home may cause embarrassment or stigma when people visit my house.
- I am worried that smart home devices may be a burden to the people who live with me.
- I am worried that smart home may replace or diminish my human contact and result in social isolation.
- I am worried that the smart home will result in my reliance on automation technology and loss of autonomy
- I am worried that the smart home devices will always be perceived as reinforcing an image of being "old" for myself.

Industry & Market Risk (IM)

The "Industry and market risk" refers to the risk of the immature and irregular market and industry development of smart homes for the elderly. It is mainly reflected in the market penetrations that stay low and are far from mass adoption, no consistency in industry standardization and regulation, no eligibility criteria about the products and services quality, the compatibility of different brands and products is poor, etc.

- I am worried that there is an absence of a comprehensive market.
- I am worried that there is no consistent standardization and regulation of the smart homes industry.
- I am worried that the product update too fast and the products I brought would be obsolete soon.
- I am worried that there are no eligibility criteria for the enterprises and service providers' quality and level.
- I am worried that the compatibility of different brands, systems, devices is terrible.
- I am worried that there is a shortage of service labor in the related aging industry.

Social Support Risk (SS)

The "Social support risk" mainly exists in the situation that the implementation of smart home products and systems need relevant social resources and forces, such as family support, peer support, community support, neighborhood assistance, institutional assistance, telemedicine services, emergency response, etc., the lack of these kinds of support will bring relevant social support risk.

- I am worried that there is no enough support from caregivers.
- I am worried that there is no enough support from medical staff.
- I am worried that there is no enough support from my family.

- I am worried that there is no enough support from my friends.
- I am worried that there is no enough support from my neighborhood.
- I am worried that there is no enough support from my community.
- I am worried that there is no enough support from organizations and institutions.

Policy & Law Risk (PL)

The "Policy & law risk" refers to the government or relevant public department and authorities that have not promulgated and issued effective policies and laws to regulate the smart home industry and provide guarantees for serving consumers. It is mainly reflected in the lack of legal framework, standards, and guidance as well as immature policy & law conduction and supervision environment.

- I am worried that there is a lack of policy or legal framework to give the standards and guidance.
- I am worried that there is a lack of policy & law conduct environment.
- I am worried that there is a lack of policy & law supervision environment.
- I am worried that there is a lack of policy & law to provide the right assurance.
- I am worried that there is a lack of legal responsibilities and professional competence of related service providers and caregivers.
- I am worried that there is a lack of legal aid if some accident happened due to technology or service problems.

Measurement-Attitude Toward Using (ATU)

The "Attitude toward using" refers to the consumers judgment, feeling and preference toward the usage of the products and services of smart homes. It exists at the level of consciousness. Consciousness is the forerunner of behavior intention.

- When I am old, I believe that smart homes will help me aging in place.
- When I am old, I believe that using smart homes will help me live a healthy lifestyle.
- When I am old, I believe that using smart homes will improve my quality of life.
- When I am old, I believe that using smart homes will bring happiness to me.
- When I am old, I believe that it is worthwhile to use smart homes.

Measurement-Behavioral Intention to Use (BIU)

The "Behavioral intention to use" refers to the consumers using motivation of the products and services of smart homes, and their intention to put this kind of motivation into real action.

- When I am old, I am willing to use smart homes.
- When I am old, I plan to use smart homes.
- When I am old, there is a high probability that I will use smart homes.
- When I am old, I will use smart homes as soon as I can.
- When I am old, I will recommend my family or friends to use smart homes.

Publication List

[1] Yuqi Liu, Tamura Ryoichi. Impact of Internet Use on Subjective Well-Being Among Future Elderly in China: The Mediation Role of Loneliness. In Proceedings of the International Conference on Kansei Engineering & Emotion Research, 2020; pp. 329-339.

[2] Yuqi Liu, Tamura Ryoichi, Yao Song. Constructing a Smart Home for Future Elders toward All-around Happiness: Taking Connectivity as the Core Element. Applied Sciences-Basel 2020, 10, doi:10.3390/app10165690.

[3] Yuqi Liu, Tamura Ryoichi. How can smart home help "New elders" aging in place and building connectivity. In Proceedings of the 2020 16th International Conference on Intelligent Environments (IE), 2020; pp. 100-107.

[4] Yuqi Liu, Tamura Ryoichi. Application of Game Therapy in the Health of Future Elderly: An Experience Design Perspective. In Proceedings of the International Conference on Human-Computer Interaction, 2020; pp. 608-625.

[5] Yuqi Liu. The application of virtual reality in empathy establishment: Foresee the future. In Proceedings of the 2020 5th International Conference on Computational Intelligence and Applications (ICCIA), 2020; pp. 188-193.

[6] Yuqi Liu, Tamura Ryoichi. Study on the Model of the Elderly's Service Needs of Smart Home: Construction and Application. In Proceedings of the International Association of Societies of Design Research Conference 2019, 2019; pp. 1-8.

Acknowledgments

I would like to give my deep gratitude to my doctoral supervisor, Tamura Ryoichi. The thesis was completed under his guidance. From the selection of the topic in the early stage, the sorting of ideas, the logic of writing, the revision of content, to the final completion, Prof. Tamura gave me a lot of valuable guidance. During these four years, Prof. Tamura has had a profound influence on me. His kindness and charming personality, rigorous and meticulous academic attitude, excellence and efficiency in work, and insightful design vision have deeply infected me. Every achievement I have acquired is inseparable from the support of my supervisor. I am very lucky to have a supervisor like him and really appreciate his teaching and patient guidance during my doctoral career. At the same time, I am very grateful to my thesis advisors, Prof. Hirai, and Prof. Ushiama. They have provided important instructions, suggestions and advice during the review and defense process, which plays a key role in improving the content and quality of my dissertation.

Moreover, I would like to thank Kyushu University for providing me an excellent platform for growth. During my doctoral study, I had the honor to go to Stanford University in the United States to study design thinking in social innovation via the Stanford-Japan exchange program, to Manchester Metropolitan University in the United Kingdom to participate in the world's largest international design academic conference IASDR, and to the Philippines to participate in the Hult Prize global innovation and entrepreneurship competition, and travel to Tokyo, Osaka and other big cities in Japan to join in international and domestic academic conferences as well as giving oral presentation and publishing papers. All of these experiences have broadened my horizons and improved my design vision. I would like to thank all the teachers in the Department of Design Strategy of the School of Design for their teaching on my study. I would like to thank the Support Center and Academic Affairs Office of the School of Design for their help and care in my daily life and the preparation of my final doctoral dissertation. I would like to thank my seniors for their influences on the formation of my research paradigm, my juniors for their help in life and communication in academia. What's more, I would like to thank the Kyushu University Foreign Student Associations (KUFSA) and the Association of Chinese Students and Scholars in Kyushu (ACSSK) for giving me the opportunity to have a cordial exchange with friends and excellent scholars from all over the world, allowing me to explore diverse Japanese cultures and bringing me a colorful after-school life during my doctoral study. I have formed a global vision and been inclusive to cultural diversity that will have a profound impact on my worldview and future design career.

I would like to acknowledge the scholarship provided by the China Scholarship Council (CSC) for my doctoral study. It makes me concentrate on my researches without financial pressure in the past four years. Thanks to the Consulate-General of the People's Republic of China in Fukuoka for its care and help for me, an overseas student in Japan. Last but not least, I want to give special gratitude to my parents and relatives. It is their love and support that give me the motivation to move forward on the academic road. The completion of my Ph.D. is just a new beginning in my life. In the future, I will continue my enthusiasm and passion for design and spare no effort to become a designer and outstanding research scholar for the sustainable development of human society and the all-around wellbeing of humankind.

Liu Yuqi

Sept 2021