ENHANCING OLDER ADULTS' TECHNOLOGY ADOPTION AND KNOWLEDGE TRANSFER OF GERONTECHNOLOGY —— A GAMIFICATION APPROACH

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Certificate of Originality

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Abstract

The confluence of two global trends, accelerated digital transformation and an unprecedented demographic shift towards an aging population, has brought about significant challenges and potential opportunities for society. Gerontechnology, which integrates technology with gerontology, is assumed to be important in enhancing the quality of life for older adults and ameliorating age-related problems. However, older adults consistently exhibit lower levels of technology adoption compared to younger generations. With the rapid evolution of technologies and the ongoing progress of digitization, the digital divide among older adults may be further exacerbated, leading to an increasing urgency to bridge this divide.

Consequently, research focusing on the acceptance and adoption of technology among older adults assumes crucial importance. Numerous studies have investigated older adults' technology usage behavior, the factors influencing their technology adoption, and the physical design of gerontechnical products. However, the exploration of supporting services in gerontechnology remains limited, and barriers to technology adoption persist among older adults.

This thesis aims to develop an effective way to enhance older adults' technology adoption and knowledge transfer. To reduce older adults' resistance and anxiety towards technology, servitization, which is a new research direction, is expected to play a major role due to its ability to add value to customers. Among various servitization strategies, gamification, with its potential to motivate people, offers a great opportunity to address the issue of technology adoption among older adults. To achieve the research objectives, a comprehensive analysis from both macro and micro perspectives has been conducted to gain insights into the current progress and future trends in the field of older adults' technology adoption, as well as their perspectives on technology and related services. From a macro perspective, a roadmap of gerontechnology products and services has been presented, reviewing the previous research outcomes and highlighting current advancements, while also identifying challenges and opportunities for future development. From a micro perspective, a face-to-face interview-based survey of 104 older adults was conducted to understand their perceptions. This survey highlighted the relatively low technology acceptance and adoption among older adults, as well as shortcomings in supportive services for gerontechnology, particularly during the initial use phase.

Building on these findings, a tailor-made gamification approach has been developed

to enhance older adults' technology adoption and knowledge transfer. To evaluate the performance of the proposed gamification approach, a case study on mobile payment in Hong Kong was conducted of 115 older adults participating in the study. The extended technology acceptance model and structural equation modeling were used for examination. The findings revealed notable gamification-induced improvements in the knowledge and technology adoption intentions of older adults, with the average self-perceived knowledge increasing from 4.66 to 7.90, and average technology adoption intention improving from 5.04 to 6.01. Moreover, significant positive relationships were observed between gamification effectiveness and technology adoption constructs.

The results of this thesis reveal a significant positive effect of gamification on the acceptance and usage of technology by older adults and a strong demand for technology supporting services. This thesis provides an effective solution for bridging the digital divide among older adults and creates a new dimension for investigating older adults' technology adoption. It offers implications for both research and practice in improving the design, development, and delivery of technologies for this demographic.

Publication arising from the study

Refereed International Journal Papers

1. An, S.*, Cheung, C. F.*, & Willoughby, K. W. (2024) A gamification approach for enhancing older adults' technology adoption and knowledge transfer: A case study in mobile payments technology. *Technological Forecasting and Social Change*, 205(August), Article 123456. https://doi.org/10.1016/j.techfore.2024.123456

2. An, S., Cheung, C. F.*, & Lo, Y. T. (2024) Improving older adults' technology adoption on mobile map: a gamification approach, *International Journal of Human-Computer Interaction*, 1-19. https://doi.org/10.1080/10447318.2024.2426914

3. Cheng, M., An, S.*, Cheung, C. F., Leung, Z. & Chun, T. K. (2022) Gerontechnology acceptance by older adults and their satisfaction on its servitization in Hong Kong, *Behaviour & Information Technology*, 42(16), 2932-2951. https://doi.org/10.1080/0144929X.2022.2151936

Refereed Conference Paper

1. An, S., Cheung, C. F., Cheng, M. & Willoughby, K. W. (2021) A Roadmap of Information and Communication Technology-Oriented Product-Service Systems for Older Adults in Hong Kong, *2021 9th International Conference on Information and Education Technology (ICIET)*, Okayama, Japan, 423-430, https://doi.org/10.1109/ICIET51873.2021.9419663

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Chapter 1 Introduction

1.1 Background of the study

The confluence of two global trends, namely accelerated digital transformation and an unprecedented demographic shift towards an aging population, have brought great challenges and potential opportunities for society. The changing demography has markedly influenced key functions and features of society, including the pension, social security, and healthcare systems, as well as the labor market, living arrangements, and family structure An et al. (2021). Technology, holding promises for improved productivity growth and enhanced well-being, can play a critical role in realizing the potential benefits of the economic and social changes engendered by aging populations (Damant et al., 2017). Specifically, gerontechnology, which integrates gerontology into technology development, aims to provide optimum living environments for older adults, ultimately increasing their quality of life in terms of good health, comfort, and safety (van Bronswijk et al., 2009). If gerontechnology becomes widely diffused among older adults, it can significantly alleviate the burden on families, communities, and society, for instance, by reducing the workload of caregivers, releasing the labor force, and providing better healthcare. Despite research acknowledging the importance and potential advantages of technology in supporting older adults' daily living and improving their overall well-being, older adults suffer a reduced rate of acceptance, usage, and ownership of advanced technologies, and sometimes they are even psychologically resistant to these technologies.

The progress of modern society is largely determined by the citizens' capacity to embrace technology, and by older adults in particular; therefore, ensuring a basic level of technology access for every citizen is key to the digitalization process (Macedo, 2017). By bridging the digital divide and providing equitable access to technology, society can harness the full potential of gerontechnology and empower older adults to actively participate in the digital world. As a result, technology acceptance and adoption by older people has become an increasingly important field of study. Many researchers in this field concentrate on identifying the reasons for the low acceptance of technology by older people (Chen & Chan, 2013, 2014a; Peek et al., 2016). Another group of scholars and manufacturers put their effort into older adults friendly design, while most of them have stemmed from the product-oriented way of delivering their offers (Huang & Oteng, 2023). Up to present, although some researchers indicate an increase in older adults' technology

usage in recent years, the technology adoption rate among them is still far from equaling that of younger people. The swift advancement of technology and the relentless progress of digitalization engender burgeoning impediments to the adoption of technology among older adults. As a result, both academic and practical considerations point to the need for an effective way of bridging the digital divide for older people.

Integrating elaborate services into products can be a chance to improve older adults' adoption of technology. This process of incorporating services is known as servitization (Baines et al., 2009). Its core focus is the development and delivery of integrated product–service solutions that offer great value to the customer and service co-creation process, which takes place between provider and customer (Kryvinska et al., 2014). There are various strategies for servitization, and one of the hottest strategies in recent years is gamification (Huotari & Hamari, 2017). It refers to an 'intentional use of game elements for a gameful experience of non-game tasks and contexts' (Seaborn & Fels, 2015). Gamification has increasingly been harnessed as a means of motivating people in varied domains, such as education, management, healthcare, marketing, and governing and also offer much potential to servitization (Deterding et al., 2011).

In current gamification research, most studies have focused on the younger generation since they have more experience with games and possess higher self-efficacy with digital technology, and thereby are potentially more attracted to game features (Koivisto & Hamari, 2014). However, prior research indicated that older adults also play and enjoy games. As a result, there is a great potential to encourage older people's adoption of technology through gamification. Several studies have been conducted regarding the gamification application in terms of improving older adults' physical health and cognitive abilities (Koivisto & Malik, 2021), while research on integrating gamification in promoting technology adoption to a wider extent has not yet been conducted, and as a servitization strategy, its feasibility towards older adults is still unknown but highly anticipated.

1.2 Research aim and objectives

This thesis addresses the pressing issue of low technology adoption among older adults, aims to enhance the understanding of older adults' technology adoption behavior and develop a gamification approach for motivating their technology adoption and knowledge transfer. Several gaps in prior research and practices around technology design,

development, diffusion, and usage for older adults are intended to be filled in this thesis. To be more specific, the thesis consists of the following objectives:

i. To obtain a comprehensive understanding of the current state and future trends of technology development, gerontechnological products and services, and social change related to older adults
ii. To identify older adults' technology adoption behavior and their view of the services for gerontechnology
iii. To develop a gamification approach and hence a servitization strategy for enhancing older adults' technology adoption of and knowledge transfer regarding gerontechnology
iv. To validate the performance of the gamification approach by applying the extended Technology Acceptance Model

1.3 Research scope and significance

The outcome of this thesis is expected to provide an effective solution for enhancing older adults' technology adoption. China, as the most populous country, faces more severe issues from population aging than almost any other country. Hong Kong has the largest aging population ratio in China and is also one of the fastest-aging societies in the world (Fang et al., 2020). As a result, with a more pressing need to relieve the pressures of an aging population, Hong Kong was selected as the research site. The target population of this research was younger older adults, as this group of people demonstrate better intelligence and capacity measurement, stronger demands for independence in life, as well as a greater potential and ability to use technological products or services. To understand the interaction between older people and technology, various types of technologies have been included in this research, and among them, information and communication technology (ICT) is the main focus as its applications are in crucial areas for gerontechnology. In terms of research methodology, this thesis employs a triangulation of literature review, roadmapping, user survey, and case study.

Bridging the digital divide among older adults is a compelling challenge to address for our society. The evolving technology, accompanied by corresponding demographic shifts in needs, expectations, and values, have surpassed existing systems and perspectives that were primarily based on the assessment of previous generations. Characterizing older

adults based on stereotypes and assumptions can result in undesired outcomes (Lee, 2022). Consequently, adopting a proactive strategy to investigate the technology inclusion among older individuals, and based on this understanding, exploring innovative methods to promote technology adoption among them is crucial in reversing the current situation. For gerontechnology developers and manufacturers, the results of this thesis should increase their understanding of senior users and facilitate a better development of gerontechnology, especially in the services aspect. From the business and marketing perspective, the gamified servitization strategy can not only contribute to the commercialization of the technological product but also enhances its attractiveness. It should also benefit the government, communities, older adults' centers, non-profit organizations, and other related stakeholders by incorporating the findings and strategies of this research into policies and initiatives to support older people's engagement with technology. Meanwhile, the theoretical framework and methodology in this research should inspire researchers in this field to provide other approaches to fill the gap in older people's technology usage, and subsequently build a better environment for older adults 'aging in place.'

1.4 Organization of the thesis

This thesis is original research, which is to develop a technological solution to address important problems encountered by society (Kothari, 2004). It basically follows the scientific method as the research methodology and adopts a problem-solving design to identify the problem, analyze the problem, and solve the problem (Pérez & Torregrosa, 1983; Zawojewski, 2013). Figure 1.1 demonstrates the framework of the whole thesis. It includes six chapters.

Chapter 1 introduces the background of the study, which are two main trends in the world—population aging and digitalization—and the research interest that has arisen from the current challenges and opportunities, research aim and objectives, as well as the significance of this study. Chapter 2 explores and discusses the existing literature on population aging, the gerontechnology concept, research and models of technology acceptance and adoption, technology acceptance for older adults, servitization related to gerontechnology, and the innovative method: gamification. The relationships among these fields are summarized and the limitations of prior studies are identified.

In Chapter 3, gerontechnology development and its acceptance among older adults are discussed. It includes two parts of work. From a macro perspective, the first part of work

reviews the recent progress of ICT for aging and the integration of pertinent product–service systems and, on that basis, constructs a roadmap that provides insights into future trends and challenges for the development of ICT-related products and services for aging. The second part of work, through a micro analysis from older adults' perspective, identifies their technology experience, factors influencing their technology acceptance, and their perceptions of the services for the related technology via a survey-based study.

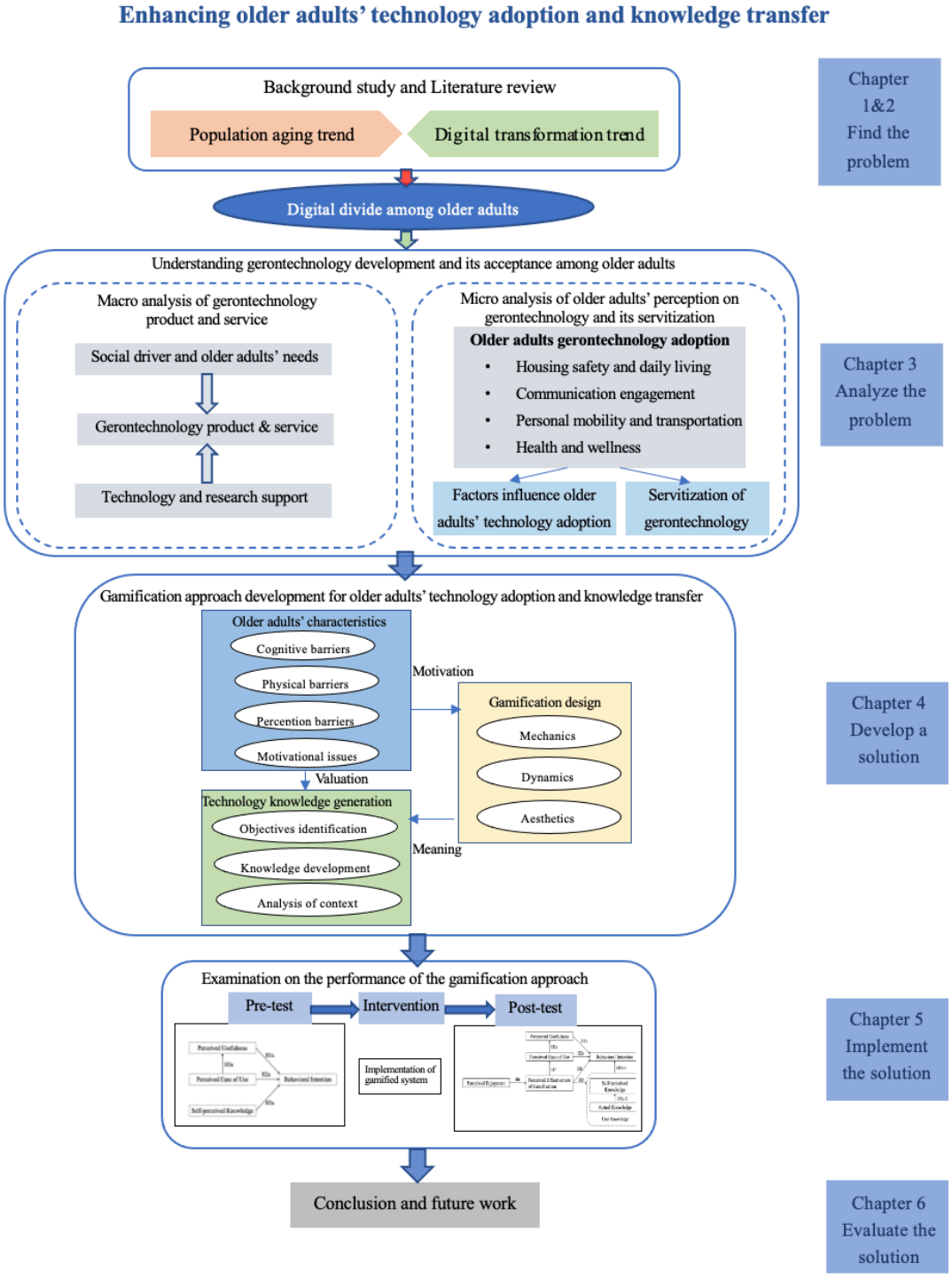

Figure 1.1 Framework of the whole thesis

Chapter 4 is devoted to solving older adults' low technology adoption issue. It develops a gamification design framework to apply to the servitization process of technology for enhancing older adults' technology adoption. A gamified mobile payment learning system is shown as a case study to demonstrate the development process. The evaluation of the performance of the proposed gamification approach is discussed in Chapter 5. It employs the extended technology acceptance model with structural equation modeling for the examination. The results demonstrate significant positive effects of gamification on the acceptance and usage of technology by older adults and evokes policy implications for the silver-hair market. Chapter 6 concludes the thesis by furnishing syntheses of the main chapters' information as well as discussions of the implications and further elaboration.

Chapter 2 Literature Review

To investigate older adults' technology usage and propose a gamified servitization strategy for improving technology adoption, this study builds upon five interconnected conceptual pillars identified in the literature: (1) population aging, (2) gerontechnology, (3) technology acceptance and adoption, (4) servitization, and (5) gamification. Together, these concepts form a comprehensive framework for understanding existing scholarly knowledge and identifying critical research gaps. Figure 2.1 illustrate linkage and rationale for their inclusion.

Population aging serves as the societal impetus for this research, highlighting the urgent need for solutions to support aging populations. Gerontechnology addresses this need by providing foundational tools to enhance quality of life for older adults. A review of gerontechnology research reveals current technological developments tailored to this demographic. However, technology alone is insufficient without adoption.

This is where technology acceptance and adoption theories become pivotal. They elucidate why technologies often fail among older adults by examining adoption barriers and behavioral rationale. The relationship between gerontechnology and adoption is inherently problem-solving: technologies must align with users' psychological and practical needs to succeed.

To bridge this gap, servitization emerges as a transformative approach. By integrating gerontechnologies into user-centered service ecosystems—informed by adoption theories—servitization ensures solutions are accessible, sustainable, and tailored to older adults' needs.

Finally, gamification acts as a strategic enhancer within servitized systems. As a subtype of servitization, it embeds motivational elements into services, making adoption engaging and sticky. This layered interplay positions gamified servitization as a promising pathway to overcome adoption challenges.

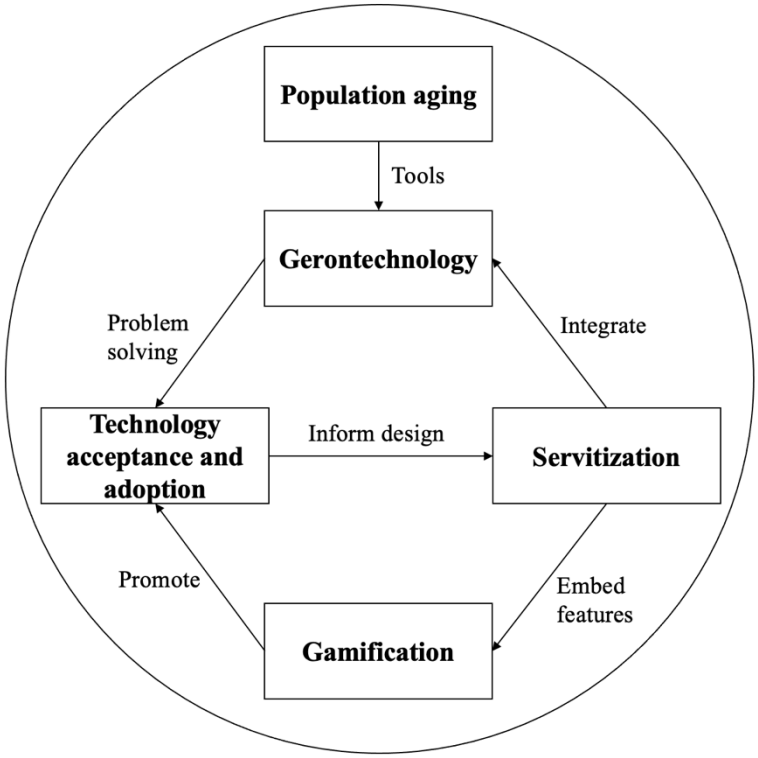

Figure 2.1 Relationship of five major concepts in literature review

2.1 Population aging

Population aging is the shift in the age distribution of a population, resulting in an increase in the proportion of older adults (Land & Lamb, 2008). Declining fertility, improved healthcare and living standards, and increasing longevity are causing the portion of older adults to rise (Bloom & Luca, 2016). The definition of older adult can vary depending on the context and purpose, while it is commonly defined with respect to their ages. In general, an older adult is typically considered to be a person aged 60 or 65 and over for different objectives (United Nations, 2019a).

According to the United Nations (2023), there were 761 million persons aged 65 years or above in the world in 2021, which means that 1 in 10 people worldwide were older people. The number of older adults is projected to more than double to 1.6 billion by 2050, so that 1 in 6 people will be an older adult. Thereby, it is becoming the dominant demographic phenomenon in the world. As defined by the United Nations (2019b), a society is considered as an ‘aging society’ when the proportion of the population aged over 65 exceeds 7% among the total population, as an ‘aged society’ when the proportion is between 15% and 20%, and as a ‘super-aged society’ when the proportion is more than 20%.

Among different regions and countries, it is affecting them at different rates and with different trajectories as shown in Figure 2.2 (United Nations, 2023). In Western Asia, Northern Africa, and sub-Saharan Africa, the number of older people is projected to grow the most rapidly over the next three decades. Northern America and Europe share the highest proportion of older individuals at present, and most countries in these regions have evolved into an 'aged society.' This demographic change has markedly influenced the key functions and features of society, including the pension, social security, and healthcare systems, as well as the labor market, living arrangements, and family structure (Sander et al., 2014). Preparing for the social and economic shifting associated with an aging population is essential for the sustainable development of the world. Iwarsson et al. (2023) contend that demographic change is typically more evolutionary than revolutionary, and the demographic trends are also more predictable, which allows stakeholders to have a great opportunity to proactively implement policies and promote behaviors that shape forthcoming demographics and alleviate the potential negative effects brought about by demographic shifts.

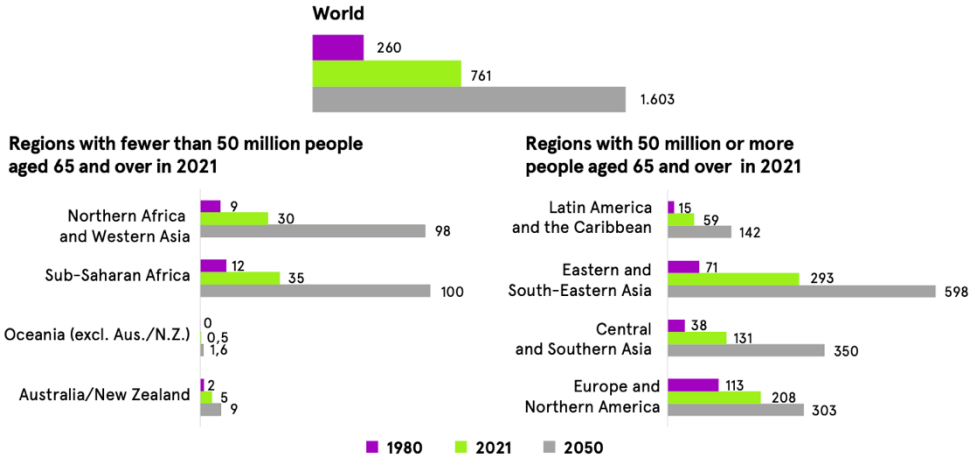

Figure 2.2 Number of people aged 65 years or above in millions, world and regions, 1980, 2021, and 2050 (United Nations, 2023)

2.1.1 Population aging in Hong Kong

According to the Hong Kong Census and Statistics Department (2023a), the proportion of older adults aged above 65 in Hong Kong reached 20.8% (1.5 million) in 2022, which is more than twice the world's average level (10%). It is now ranked the 7th older adults fast-growing region in the world. By 2050, Hong Kong is expected to have the highest share of older population, where the percentage of people aged 65 or above will

increase to 40.6%. As a region with more severe population aging issues than other regions, it is more urgent for researchers and all other related stakeholders to deal with the challenges raised by population aging in Hong Kong.

When inspecting the movements of aging-related demographic parameters in Hong Kong, it can be observed that the distinct expansion of the older population group has been due to a decline in fertility rate as well as extended life expectancy (Hong Kong Census and Statistics Department, 2016). The fertility in Hong Kong has presented a decreasing trend over the past 30 years. The total fertility rate was 772 in 2021, which is far below the replacement level of 2100 (Hong Kong Census and Statistics Department, 2023b). Wong and Yeung (2019) analyzed that the low fertility rate was partly caused by the trend of postponing marriage and the preference for having few children. At the same time, benefiting from good-quality healthcare and positive social conditions, Hong Kong has led the world's life expectancy since 2010 (Chung & Marmot, 2020). The average life expectancy was 83.2 for men and 87.9 for women in 2021. The population aging phenomenon can be further analyzed by the dependency ratio, which refers to the proportion of the non-working population aged 65 and above being supported by the working population. In 2021, this ratio was 28.2, and it is expected to increase to 60.6 in 2069, imposing a heavier burden on society (Hong Kong Census and Statistics Department, 2023a). To respond to the continuing rise in the number of elderly and protect the elderly's life quality, the government follows a policy direction of promoting 'aging in place as the core, with institutional care as back-up' (The Government of Hong Kong, 2022).

Given Hong Kong's rapidly aging population and the strong demand for "aging in place," it has been selected as the research setting for this study. Nevertheless, population aging poses significant challenges for many regions and countries worldwide. Asia and Europe are home to the majority of the world's oldest populations. Currently, mainland China has the largest elderly population, with individuals aged 65 and above reaching 216.76 million in 2023, accounting for 15.4% of the total population, which indicates that the country has transitioned into an aged society (Gao et al., 2024). Japan has the highest proportion of older adults, with those aged 65 and above comprising 30.2% of its population in 2023, followed by Italy (24.9%), Finland (23.9%), Puerto Rico (23.8%), and Portugal (23.7%) (Richter, 2024).

With an undeniable trend toward the rise of aging population across nations and universal challenges of aging, such as aging-related health issues, shortage of caregivers,

and social support systems, this research can contribute not only to addressing population aging in Hong Kong but also offer insights with potential global relevance.

2.1.2 Aging in place

'Aging in place' describes the phenomenon where, when considering the lifestyles of older adults, many prefer to remain in their own homes rather than move to nursing homes due to the comfort, convenience, independence, and safety provided by their familiar surroundings (Peek et al., 2019). The concept of aging in place extends beyond the living space to encompass local communities and neighborhoods. Research has shown that older adults usually attach special meaning to their living space, and the long-term emotional attachment to their home has been found to contribute positively to their well-being (Ahn et al., 2020). As older people's physical circumstances will change with age, even if they have good health, some changes or adaptations will be required in the home environment, public facilities, and the integration of home and public to maintain their standard of life.

Technology has been identified as a potential means of promoting aging in place, often referred to as gerontechnology, and is designed to support activities of health, daily living, communication, physical activity, mobility, and safety. However, despite the proven significance of these technologies in successful interventions, their usage has been limited (Wang et al., 2019). Various factors may influence the technology adoption by older adults and their willingness to change their use of technology in their daily lives, which will be further discussed in subsequent sections.

2.2 Gerontechnology

Gerontechnology aims to study how to match the needs and expectations of the older adults in their actual living environments with appropriate innovative and existing technology (Bronswijk et al., 2009). In practice, it often encourages independent living and social participation among older adults through advanced products and services (Pekkarinen et al., 2013). Accordingly, gerontechnology is an interdisciplinary field combining aging (gerontology, sociology, psychology, physiology, etc.) and technology (physics, chemistry, engineering, robotics, design, etc.), and its research outcomes form the foundation for manufacturers, engineers, designers, and health professionals to promote the life quality for older people. Gerontechnology is also referred as 'AgeTech' or 'Silver-Tech' in some European countries and the United States. This term is overlapped

and commonly used interchangeably with the concept of smart technology, assistive technology, and health technology when considering older adults, although the scope and boundary among these terms still remain ambiguous (Kim et al., 2021).

2.2.1 Evolution of the gerontechnology field

Before the 1990s, there were already many scientific disciplines which put efforts into aging-related research. Whereas most of them derived from the social sciences and life sciences, some studies involved ergonomics and human factors, while the activities from technology, engineering, and design fields were rarely considered. As a result, a small research group led by Graafmans and Brouwers started to develop a research and education program on aging-related technology in order to integrate engineering science into aging studies and the term 'gerontechnology' was invented at that time in 1988 (Graafmans & Brouwers, 1989). As the inventor of the term 'gerontechnology,' Graafmans could be considered as the father of this field. In his first gerontechnology-related publication, 'Gerontechnology, the modeling of normal aging,' the concept and definition of 'gerontechnology' was introduced and the man–product–environment interaction model was used to interpret the interaction between engineer and old consumer (Graafmans & Brouwers, 1989). This model was further refined by Bouma and Graafmans (1992) into the human–technology–environment interaction model, with more emphasis on old people, and it became the starting point of the first conference on gerontechnology.

Later on, several international conferences were held successively and the International Society for Gerontechnology (ISG) was founded in 1997, which convinced many social, engineering, technological, and medical researchers to come on board. The network of gerontechnology has been steadily built, and the basic concepts and initial models were formed. That was the incubation stage of gerontechnology, where gerontechnology emerged as the result of the attention to the aging issue by professionals from various disciplines (Bronswijk et al., 2009).

The 2000s could be considered as its growth period. As the aging problem became increasingly revealed, more and more researchers recognized the importance of developing gerontechnology. Many studies have acknowledged the advantages of applying gerontechnology for older adults' living, including benefits for providing socializing, safety, entertainment, healthcare, and convenience; overall improvement of older people's life quality; and the reduced potential cost for the care and treatment of older people

(Klimova, 2016). As a result, increasing research in gerontechnology has poured out, with many researchers incorporating this concept into their product design activities. Nevertheless, the research trend is changing along with the fast-changing technological environment as well as aging people's habit and behavioral shifts.

Fozard et al. (2000) investigated the relationship between gerontechnology and aging and determined the importance of user needs and technology preferences. Bouwhuts (2000) not only focused on the usability of products but was also concerned about how the products fit into the lifestyle and environment of the user personally. Molenbroek and de Bruin (2006) suggested a product design process with user involvement to demonstrate a better understanding of the fit of products. Higgins and Glasgow (2012) investigated the age-related behavior towards technology in order to facilitate the product development of gerontechnology. In line with these aforementioned studies, Peine et al. (2014) further argued that the majority of previous approaches to new technology design for older adults fell into the trap of negative stereotypes about older adults.

As a result, they proposed a new concept called "innosumer," which regarded older adults as active co-creators, to study the relationship between technology and aging for the benefit of the product design practice for older people. Lee and Coughlin (2015) conducted a user-oriented study to understand how user involvement can be applied to gerontechnology development, and two case studies (i.e., software and hardware) were carried out to demonstrate the user involvement practices in the product design activities. Ofli et al. (2015) developed an exercise coaching system with different fitness applications and highlighted the lessons learnt regarding product design for elderly people.

With the transformative power of Artificial Intelligence (AI), many recent studies have focused on AI application in gerontechnology, such as assistive robotics, algorithms for disease management, and smart wearables (Kuziemsky et al., 2019; Shin et al., 2018; Werner et al., 2020). In the ongoing development of AI-based gerontechnology, ethical concerns have been raised. To address this, Rubeis (2020) proposed a systematic conceptualization of AI-based gerontechnology design from an ethical perspective.

On the whole, previous studies mainly focused on producing specific guidelines to integrate gerontechnologies into physical products and the interactions between technology and older people, such as technology acceptance and adoption. While the service aspect has been neglected by both academia and industry, there is a need to support the integration of gerontechnology, products, and services while taking into account

environmental, physical, psychological, and social factors to meet the specific needs of older people, in order to provide optimal independent living environments.

According to this need, the literature suggests that innovation strategies for the development of products integrated with services and technologies for older people are one of the most significant issues for the stakeholders (An et al., 2021; Chang et al., 2019; Menghi et al., 2018). In fact, in Hong Kong, the government has recognized the difficulty for older people to adopt technology and the importance of supporting services. Hence, the government has launched a series of ICT projects since 2012 to enhance older adults' access, knowledge, and skills with regard to digital devices (OGCIO Hong Kong, 2022). Nevertheless, government power alone is far from enough to meet older adults' demand for services. The government's role is more related to advocacy and providing supplementary support to assist the elderly to learn technology. Manufacturers and companies that have adopted gerontechnology, designers, and engineers should be the main forces providing services to support older adults' technological product usage and thereby improve their technology acceptance.

2.2.2 Gerontechnology categories

Various studies have supplemented the concepts of gerontechnology with its category criteria. Bouma with van Bronswijk and Fozard established a series of matrixes of gerontechnology, which lays a foundation for this field. Bouma et al. (2007) proposed a cross-fertilization matrix for demonstrating the scope of gerontechnology as shown in Figure 2.3. This classification method integrated disciplines of aging and innovative technology. A wide range of segments from physiology nutrition to architecture building was involved in the scope of gerontechnology. Moreover, this framework innovatively put business management into the technology category, which enables technological products, services, and infrastructures to be commercialized in the market.

		Technology					
		(Bio)Physics (Bio)chemistry	Architecture Building	Information Communica-tion	Mechatronics Robotics	Ergonomics Design	Business management
Gerontology	Physiology Nutrition						
	Psychology Social psychology						
	Sociology Demographics						
	Medicine Rehabilitation						

Figure 2.3 Cross-fertilization matrix of gerontechnology (Bouma et al., 2007)

Modifying the cross-fertilization matrix and integrating it with other previous matrixes, van Bronswijk et al. (2009) formulated three matrixes for gerontechnology research, design, and engineering project use. One of the matrixes recognizes the main goals of technological intervention in combination with gerontechnology application domains from the engineering perspective, which is called the impact matrix of gerontechnology. It is the first framework that combines the different disciplinary groups of the aging process with innovative technology. As shown in Figure 2.4, this matrix defines five domains of life activity in relation to technology and four goals of an aging population, which forms the fundamental concept underlying gerontechnology (Bouma et al., 2007, 2009; van Bronswijk et al., 2002).

		Application domain				
		Health Self-esteem	Housing Daily living	Mobility Transport	Communi-cation Governance	Work Leisure
Main goal	Enrichment Satisfaction					
	Prevention Engagement					
	Compensation Substitution					
	Care support Care organization					

Figure 2.4 Impact matrix of gerontechnology (van Bronswijk et al., 2009)

The application areas in this matrix were still goal-oriented; therefore, Peek et al. (2016) modified it by addressing the characteristics of technology. Obi et al. (2013) classified gerontechnology services and applications based on the elderly's special needs, which are needs for health, safety, independence, mobility, and participation. It could be

further subdivided through its attributes and functions, including the areas of supporting technologies for the functioning of older adults; accompanying technologies; emotions, recognition, and mood regulation; personalized adaption of the environment; social cognitive robots and agents; entertainment technologies; smart telehealth, telemedicine and communication services; and social network technologies.

There are also some studies classifying the gerontechnology from the 'aging in place' perspective. Satariano et al. (2014) offered a categorization method with three prominent technology categories: technology type, outcomes expected through technology, and technology functions. Laurie (2019) categorized gerontechnology into four market segments, which are communication engagement, safety and security, learning and contribution, and health and wellness. The researcher believes that each category is useful in itself, but they can together provide a more fulfilling and interactive life for the elderly.

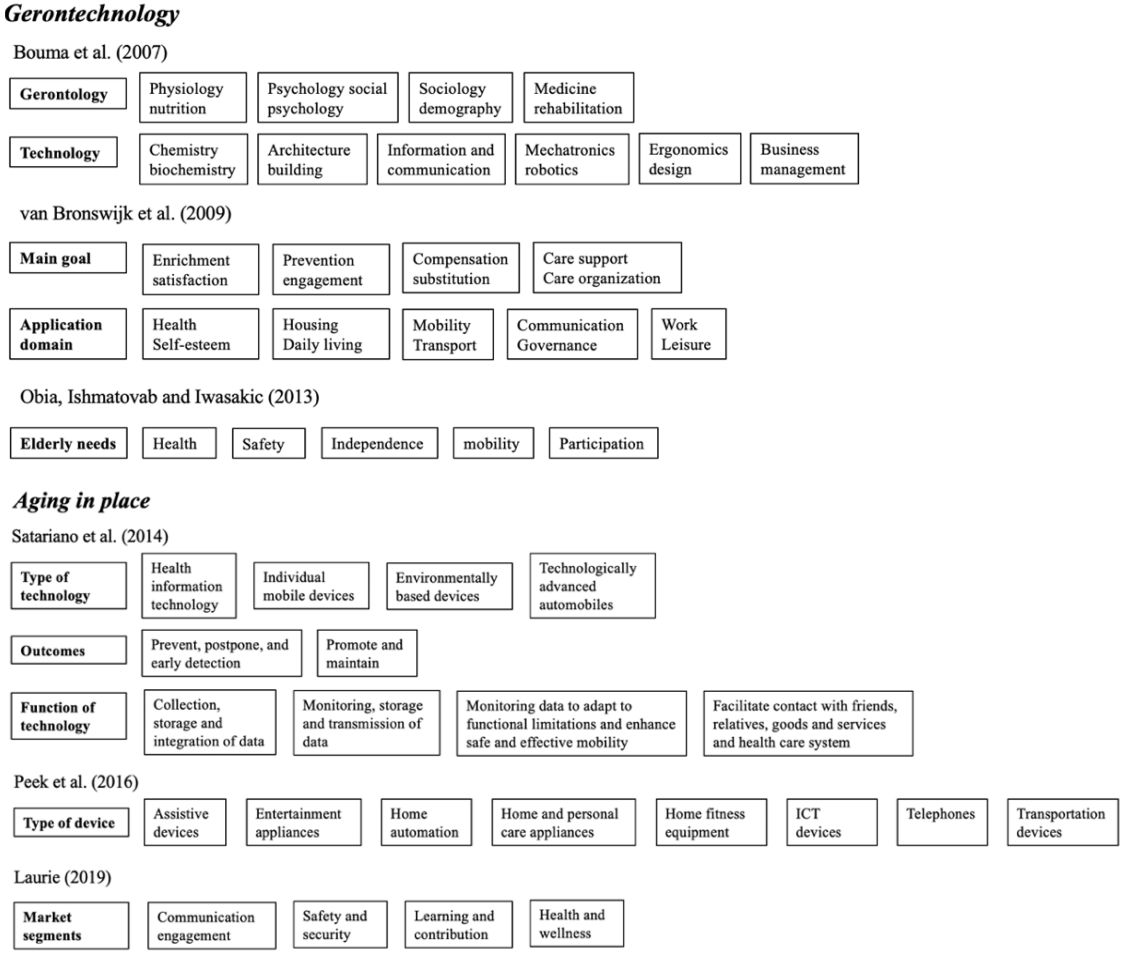

Figure 2.5 Gerontechnology classification matrixes

Figure 2.5 demonstrates a summary of the gerontechnology classification methods. This is the first work that reviewed and summarized the different classification methods for gerontechnology, which allows researchers to obtain a clearer identification and

description of gerontechnology as well as a better understanding of the relationships and connections among gerontechnology categories from different angles.

2.3 Technology acceptance and adoption

Recognizing the needs, perceptions, and behaviors of individuals is the primary step for any products and services development, and it is also necessary for future improvements to be made. As a result, understanding the drivers of users' acceptance of or resistance to technology is critical for investigating gerontechnology and developing products and services for older adults.

2.3.1 Definition of technology acceptance and technology adoption

Although 'technology acceptance' and 'technology adoption' are used interchangeably in some cases, it is important to distinguish the difference between these two terms (Renaud & Biljon, 2008). Technology adoption is the phase starting with the users' awareness of the technology, followed by their research and deliberation, and ending with users' embracement and full use of technology (Bouwman et al., 2005). As opposed to adoption, acceptance is defined as the act of agreeing to something. As a result, technology acceptance refers to the users' attitudes, perceptions, and actions towards a new technology, and it may be influenced by varied factors (Kaldi et al., 2008). It can be seen that both terms are related to the decision to use a new technology, while in the cases in which a user has purchased a new technology but not yet adopted it, technology acceptance plays an important role. If the user does not accept a technology, full adoption is not likely to occur. Additionally, technology acceptance is not a fixed state. The first time of acceptance is not an indication of long-term acceptance. While, adoption can occur without full acceptance, though this is less common and often problematic. For instance, they may adopt a technology due to pressure from family, caregivers, or healthcare providers, even if they do not fully accept or understand it. Secondly, it may happen when they lack alternatives. When it happens, it may challenge traditional technology acceptance models (e.g., TAM and UTAUT), which assume that acceptance (attitude and intention) precedes adoption (behavior). Therefore, traditional models may need to incorporate external factors (e.g., social pressure, lack of alternatives) that can drive adoption without acceptance. Besides, researchers should explicitly differentiate between these concepts and measure them separately to understand their relationship. Moreover, models should account for the

possibility of abandonment or discontinuation if adoption occurs without acceptance. For the research models in this study, as it only focuses on older adults' behavioral intention, this issue do not influence this research.

Despite the differences, they are both critical for practitioners and researchers for understanding the issue that influences users' decision to adopt a specific technology so as to help them arrive at better ways to design, evaluate, and predict user reactions to new technologies (Taherdoost, 2018).

2.3.2 Technology acceptance and adoption models

A number of frameworks and models have been proposed to understand the rationale behind users' technology adoption behavior and the factors which influence their acceptance.

(i) Diffusion of Innovation Theory (DOI) (Rogers & Shoemaker, 1971)

This theory can be traced back to Everett Roger's work in 1960. The model introduces four factors that influence the adoption of a new idea: the innovation itself, the communication channels used, the time frame, and the social system involved. The process of diffusion consists of five distinct stages as shown in Figure 2.6, which are knowledge, persuasion, decision, implementation, and confirmation. It results in five categories of users: innovators, early adopters, early majority, late majority, and laggards (Figure 2.7) (Rogers & Shoemaker, 1971; Rogers et al., 2014).

This model not only can be used at individual and organizational levels, but also provides a theoretical framework for understanding technology diffusion at a global level. The DOI model excels at investigating system characteristics, organizational attributes, and environmental factors that influence innovation adoption.

However, it has relatively less explanatory power and is less practical for predicting specific adoption outcomes compared to some other technology acceptance models. One of the limitations is the assumption of a homogeneous population, but this may not apply equally across all cultures, industries, or technologies. Moreover, the theory emphasizes adoption but pays less attention to discontinuance use or abandon (MacVaugh & Schiavone, 2010).

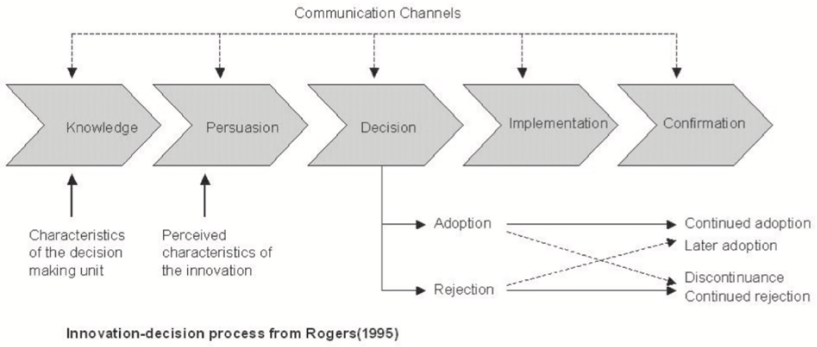

Figure 2.6 Innovation-decision process (Rogers et al., 2014)

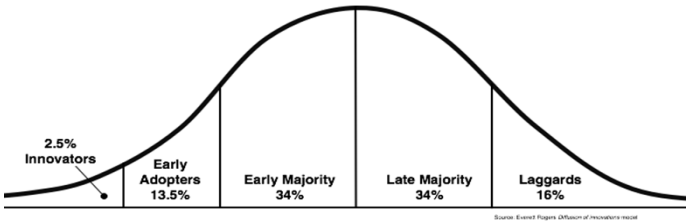

Figure 2.7 Diffusion of innovation (Rogers et al., 2014)

(ii) Theory of Reasoned Action (TRA) (Fishbein & Ajzen, 1977)

This model is developed from a social psychology setting, and it has recently commonly been used to investigate individuals' ICT adoption behavior. It predicts and explains human behavior through three main cognitive components: attitudes (A), behavioral intention (BI), and subjective norm (SN) (Figure 2.8). TRA posits that a person's intention to carry out a behavior is the primary predictor of whether they will actually perform that behavior. Moreover, the subjective norm surrounding the act also contributes to the likelihood of the person performing the behavior. It suggests that stronger intentions lead to greater effort to perform the behavior, which in turn increases the probability of the behavior being carried out.

Although TRA was originally developed by Fishbein and Ajzen within the field of health to understand health-related behaviors, its principles can be applied more broadly to comprehend and even forecast a wide range of human behaviors, regardless of context. To enhance the robustness between intention and attitude, various methods have been established, including considerations of generality, time horizon, target, context, and action. It also has its limitations (Hagger et al., 2002), such as lacking adequate treatment of the role of habit formation, the process of cognitive deliberation, potential misunderstandings that can arise from survey-based assessments of attitudes, subjective norms, and intentions, as well as the influence of moral factors on technology adoption decisions. Moreover, the

actual performance of a behavior does not always require a strong preceding intent. In fact, attitudes and behaviors may not always be directly linked by intentions, especially when the behavior itself does not demand substantial cognitive effort from the individual.

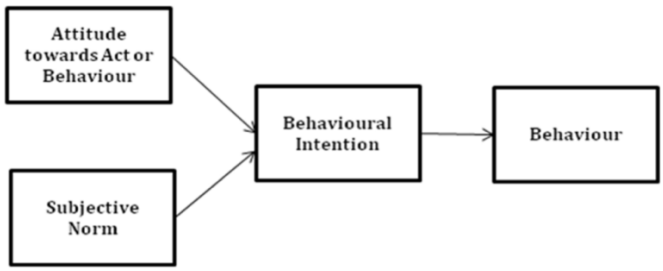

Figure 2.8 Theory of Reasoned Action (Fishbein & Ajzen, 1977)

(iii) Theory of Planned behavior (Ajzen, 1991)

This model is developed based on TRA and it extends TRA by adding a new construct: perceived behavioral control (PBC) in the model as shown in Figure 2.9. Perceived behavioral control refers to 'people's perception of the ease or difficulty of performing the behavior of interest.' The Theory of Planned Behavior (TPB) addresses a key criticism faced by the TRA—that it relies on a relatively static conceptualization of attitude, limiting its ability to predict behavioral outcomes. The roots of the TPB's concept of PBC can be traced back to Bandura's Self-Efficacy Theory (SET), which itself emerged from the broader Social Cognitive Theory. While the Theory of Planned Behavior is grounded in cognitive processing, some scholars have criticized this foundation. More recently, other researchers have argued that the theory fails to account for an individual's needs prior to engaging in a particular action—needs that can influence behavior independently of expressed attitudes. Moreover, some researchers have challenged the proposition of TPB, that intentions and behaviors are merely consequences of social norms, attitudes, and perceived behavioral control by experimental studies. Specifically, the study conducted by Sussman and Gifford (2019) suggests that the relationships between these three key elements and intentions may in fact be bi-directional, rather than the unidirectional associations proposed by the theory.

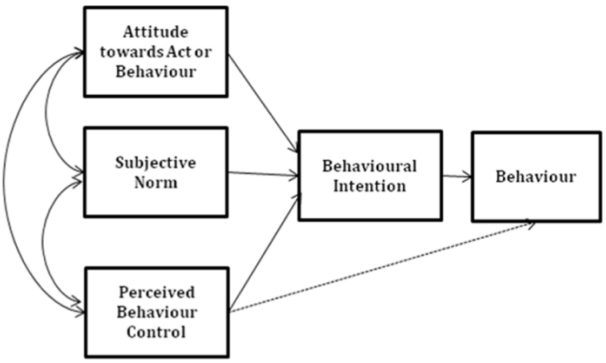

Figure 2.9 Theory of Planned Behavior (Ajzen, 1991)

(iv) The Social Cognitive Theory (Bandura & Cervone, 1986)

Rooted in social psychology, the Social Cognitive Theory (SCT) proposes a triadic, reciprocal model for predicting both individual and group behaviors. The key factors in this model are behavioral, personal, and environmental, which interact bi-directionally as depicted in Figure 2.10. Within this framework, the behavior factor focuses on issues such as technology usage, performance, and adoption. The personal factor contains an individual's personality traits, demographic characteristics, and cognitive abilities. The environmental factor includes the physical and social elements external to the person.

Crucially, SCT emphasizes the role of cognitive processes, particularly outcome expectations and self-efficacy, in determining behavior. Individuals are theorized to be motivated by anticipated personal and performance-related outcomes, which are in turn influenced by their beliefs in their own capabilities (self-efficacy). Additionally, SCT posits that two opposing factors influence user behavior: affect and anxiety. Affect, or the degree to which an individual enjoys their work, positively contributes to desired behaviors. Conversely, anxiety, or the anxious reactions experienced when performing unfamiliar tasks, can negatively impact behavior.

Researchers often incorporate SCT-derived elements including affect, self-efficacy, anxiety, and outcome expectations when assessing and understanding an individual's adoption and usage of various technologies. More recently, researchers also tried applying it to explain the variance in preventive behavior during the Covid-19 pandemic (Hagger & Hamilton, 2022). However, in terms of the model itself, because it is a vast theory.. Some critics argue that the theory is not entirely unified but functioning more as a loosely connected set of behavioral influences. Due to these limitations, social cognitive constructs remain largely theoretical. Many researchers argue that explanatory power of the theory can be strengthen by newer theories with better predictive power (Bennett et al., 2018).

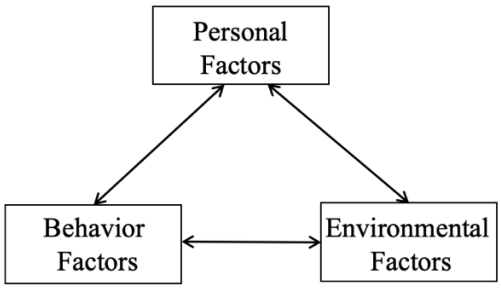

Figure 2.10 Social Cognitive Theory (Bandura, 2000)

(v) Technology Acceptance Model (Davis, 1989)

The Technology Acceptance Model (TAM) is derived from the TRA model. As a robust, powerful, and parsimonious model, this model has been widely used for predicting user acceptance. The appeal of the TAM lies in its simplicity, centering on just two key factors—perceived usefulness and perceived ease of use—that heavily shape user attitude, contributing to its widespread application (Figure 2.11). PU is defined by Davis (1989) as "the degree to which a person believes that using a particular technology would enhance his or her life" and PEOU as "the degree to which a person believes that using a particular technology would be free of effort." Moreover, PEOU has been considered as a determinant of PU (Pai & Huang, 2011), which assumes that with all else being equal, users consider a technology to be more useful when it is more effortless (Davis, 1989). These can be determined as an unfavorableness and favorableness toward the system.

Davis and his co-workers found that attitude did not completely mediate the PU and PEOU. Therefore, the behavioral intention substituted the attitude, which is an affective evaluation of the potential consequences of the behavior.

TAM is widely used in different technology contexts to study the adoption behaviors. While PU, PEOU, and behavioral intention to use (BI) have long served as core predictors in the TAM, their explanatory power remains limited (Bagozzi, 2007). Empirical studies reveal that these factors account for only about 40% of the variance in technology adoption, leaving a substantial portion of user behavior unexplained. There are other factors influence technology adoption (Attié & Meyer-Waarden, 2022).

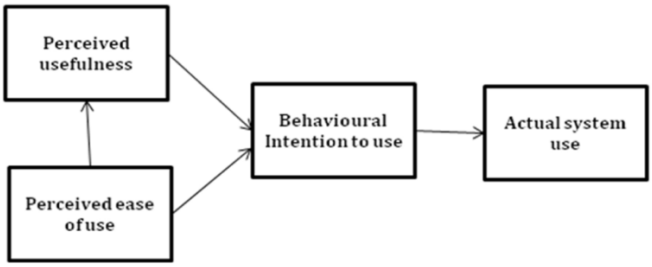

Figure 2.11 Technology Acceptance Model (Davis, 1989)

(vi) Technology Acceptance Model 2 (Venkatesh & Davis, 2000)

Building upon the foundational Technology Acceptance Model (TAM), Venkatesh and Davis (2000) proposed an expanded version known as Technology Acceptance Model 2 (TAM2). This extended model incorporated two additional groups of constructs as demonstrated in Figure 2.12. The first group of constructs added to TAM2 were social influence factors, including image, subjective norms, and voluntariness of use. The second set of constructs introduced in TAM2 were cognitive factors, such as result job relevance, demonstrability, and output quality. The inclusion of these two sets of constructs was intended to provide a more comprehensive explanation of the factors driving technology acceptance through their effects on the key TAM construct of perceived usefulness. Nevertheless, similar to TAM, TAM2 also account for only 40% of a technological system's usage, therefore other antecedents must be studied (Legris et al., 2003).

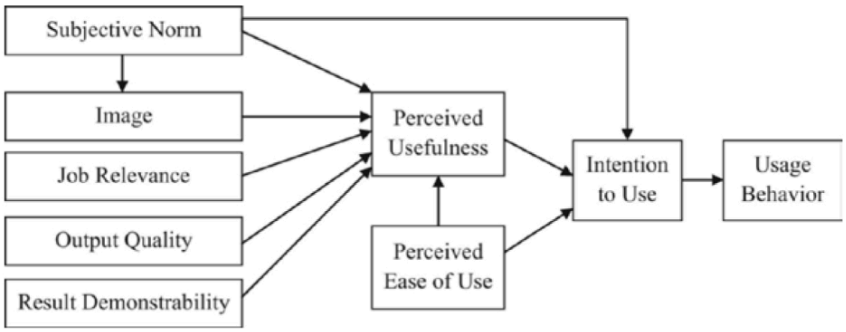

Figure 2.12 Technology Acceptance Model 2 (Venkatesh & Davis, 2000)

(vii) The Motivation Model (Davis et al., 1992)

The Motivation Model is a theoretical framework that seeks to explain and predict human behavior by focusing on the key drivers and incentives that motivate individuals (Figure 2.13). At the core of the Motivation Model are two primary types of motivations

that influence behavior: extrinsic and intrinsic motivations. Extrinsic motivations refer to external rewards or benefits that can be obtained through a particular behavior, such as improved job performance, increased status, or financial gains. In contrast, intrinsic motivations are internal drives or inherent satisfaction derived from the activity itself, such as the enjoyment, curiosity, or sense of accomplishment experienced when using a new technology. The Motivation Model posits that both extrinsic and intrinsic motivations can shape an individual's intention to use a technology, which in turn influences their actual usage behavior. Extrinsic motivations, such as perceived usefulness or expected performance improvements, can directly drive technology adoption. Intrinsic motivations, such as perceived enjoyment or personal growth, can also positively influence usage intentions.

Additionally, the Motivation Model acknowledges the role of other factors, such as social influence, organizational support, and individual differences, in mediating the relationship between motivations and technology usage. These contextual and personal variables can either strengthen or weaken the impact of extrinsic and intrinsic motivations on an individual's behavioral intentions and actual technology use. Nevertheless, this model has its drawbacks (Bandhu et al., 2024). Researchers point out that the motivation model only focus on psychological acceptance but neglects structural barriers, such as cost, accessibility, and device availability. Secondly, it lacks attention to negative motivations, such as anxiety, risk, and privacy concerns.

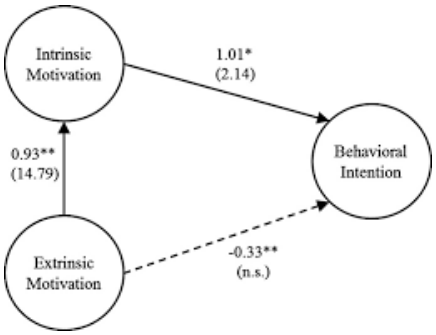

Figure 2.13 Motivation Model (Davis et al., 1992)

(viii) The Model of PC Utilization (Thompson et al., 1991)

The Model of PC Utilization (MPCU) is primarily concerned with the extent of personal computer (PC) usage by workers in scenarios where the use is not mandated by the organization, but rather contingent on the individual user's discretion. In such a voluntary usage setting, the MPCU posits that a worker's usage of a computer is likely to

be influenced by various factors. These include the individual's affective feelings toward using PCs, the prevailing social norms regarding PC use in the workplace, the user's general habits related to computer usage, the consequences that the user expects to experience by using the PC, and the extent of facilitating conditions present in the workplace to enable PC use.

While habits are recognized as a strong predictor of behavior, the MPCU model has excluded this construct, focusing instead on six key determinants of PC usage behavior. These are: complexity, facilitating conditions, perceived consequences, long-term consequences of use, social influences, and job fit.

The MPCU framework, as illustrated in Figure 2.14, provides a comprehensive understanding of the multifaceted factors that shape an individual's decision to utilize personal computers in a voluntary work environment, which offers valuable insights into the adoption and continued use of technology by workers.

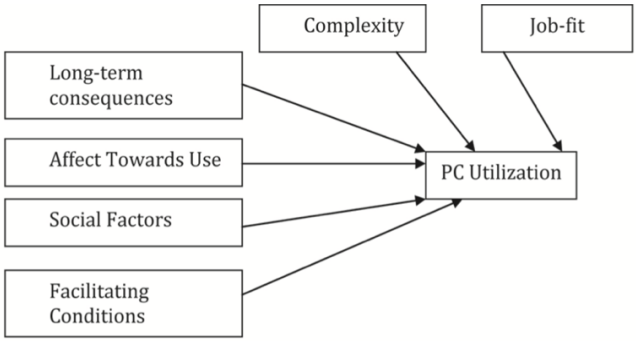

Figure 2.14 The Model of PC Utilization (Thompson et al., 1991)

(ix) Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh et al., 2003)

This theory was postulated in 2003 by Venkatesh et al. through a systematic review and consolidation of the constructs of eight earlier models, which were TRA, TPB, TAM, TAM2, MM, DOI, SCT, and MPCU. To develop the unified model, seven constructs used in earlier models were tested, and finally, this model identified four most substantial constructs: effort expectancy, social influence, performance expectancy, and facilitating conditions (Figure 2.15). The UTAUT model posits that self-efficacy, attitude toward using technology, and anxiety do not directly influence behavioral intention, as they are fully mediated by the construct of effort expectancy, which has been incorporated into the model as performance expectancy. As a result, these three constructs were removed from

the final unified framework. Additionally, four significant moderating variables have been identified in this model, which are gender, age, voluntariness of use, and experience.

UTAUT is one of the most commonly used technology acceptance models for current studies. Compared to earlier models, which can only explain 30%-40% of the variance in adoption behavior, this theory is able to explain 70% of the variance, whereas it has been criticized that this model is overly complex, is not a parsimonious model, and is unable to explain individual behavior.

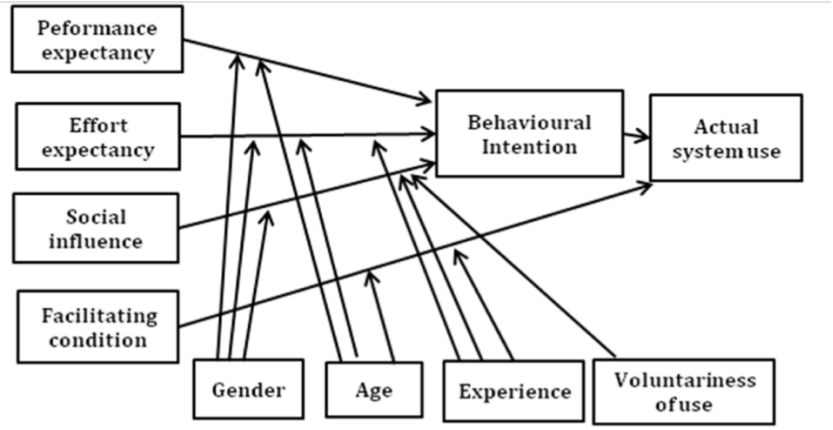

Figure 2.15 Unified Theory of Acceptance and Use of Technology (Venkatesh et al., 2003)

Figure 2.16 below demonstrates the most popular theories and models of technology acceptance/adoption and the relationship among them. Over time, it seems that researchers have attempted to revise or add to the previous models in order to enhance the applicability and robustness of these models. Among them, the TAM and UTAUT are the two most commonly used models. The TAM, which provided an important basis for the subsequent models, such as TAM2 and UTAUT, has been referenced and implemented to a larger extent (Tang & Chen, 2011). UTAUT synthesized and consolidated eight prominent technology acceptance models and added new variables and theories into the field of knowledge. A study conducted by Dwivedi et al. (2010) revealed a notable shift in the focus of researchers, who are increasingly citing and utilizing the UTAUT framework over the TAM when examining technology acceptance and usage.

However, in the older adults related studies and healthcare domain, the TAM is more frequently used than UTAUT. As reported by AlQudah et al. (2021), 76 of 142 studies in their review employed the TAM and its extensions to explore the user's technology acceptance in healthcare, and UTAUT and its extensions are only applied by 26 studies. The research profile of older adults is similar (Chen & Chan, 2011; Yau & Hsiao, 2022).

We noted that both the TAM and UTAUT were not developed within the older adults' technology usage setting. As a result, it is necessary to add variables to extend the original technology acceptance models to better fit the context, and the TAM seems to have a broader scope for extension (Ammenwerth, 2019).

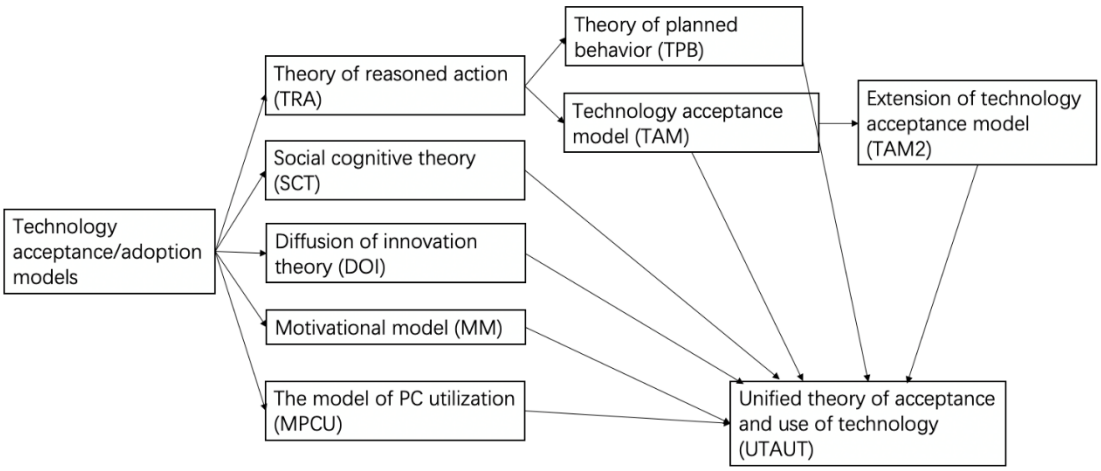

Figure 2.16 An overview of Technology Adoption / Acceptance Models

2.4 Older adults' technology acceptance

A certain portion of studies share a consensus view of technology as favorable by providing older adults with 'overwhelmingly positive experiences and outcomes' (Macedo, 2017). The benefits of technology for older adults have been acknowledged in previous research, including but not limited to improving older adults' life quality, independence, and social interaction, and reducing the burden on society (Peek et al., 2014). Despite these benefits, this group of people still exhibit lower levels of technology use compared with other groups of people (Seybert & Reinecke, 2014; Smith, 2014). The recent outbreak of COVID-19 facilitated people's use of some technological products due to the restrictions on direct social contact (Alghamdi & Alghamdi, 2022). People had to rely more on digital means to accomplish things and communicate in society. At the same time, this social change exposed the barriers to and problems with older adults' technology usage. It forced older adults to actively or passively learn technologies in order to address their living demands, such as contacting friends or relatives through video communication.

Some researchers indicate a vigorous increase in older adults' ICT usage in recent years. For instance, in Hong Kong, the internet usage (including assessing through varied

devices, e.g., computer, smartphone, tablets) for people aged over 65 increased from 65.9% in 2020 to 81.8% in 2022, and the percentage of older adults who had knowledge of using personal computers improved from 49.5% in 2020 to 60.3% in 2022, which was the highest growth rate among all age groups as demonstrated in Figure 2.17 and Figure 2.18 (Hong Kong Census and Statistics Department, 2023c). Nevertheless, usage data still evidence a 'digital divide' among older adults, which suggests a lagging adoption of technology compared with the younger generation.

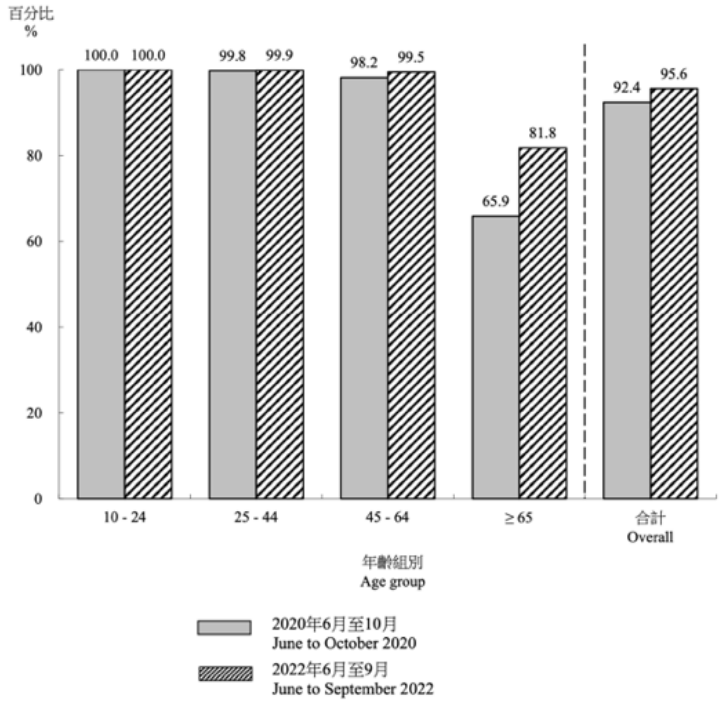

Figure 2.17 Usage of the internet during 12 months for persons aged 10 and over (Hong Kong Census and Statistics Department, 2023c)

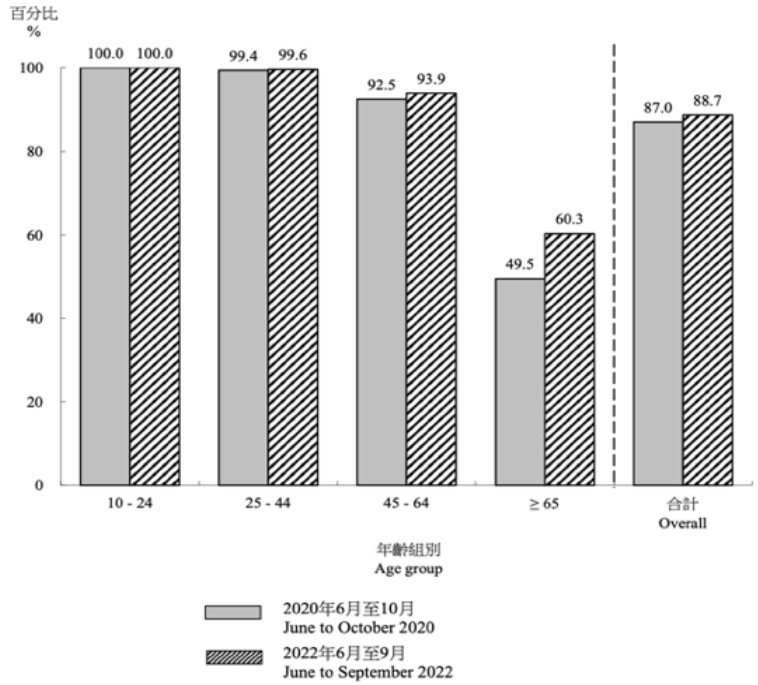

Figure 2.18 Knowledge of using personal computers for persons aged 10 and over (Hong Kong Census and Statistics Department, 2023c)

Broady et al. (2010) debate whether older adults are not necessarily negatively disposed to technology, but to cope with their declined cognitive capability, they are selective in determining what they believe to be both beneficial and necessary for their lives. This argument is supported by Peek et al. (2014), who found a positive relationship between the need to use technology and its effective utilization, where people were more likely to use a technology only if they recognized a need. Hill et al. (2015) argued that in many cases, even if older adults acknowledge the benefit of a new technology such as the convenience of online payment and mobile payment, it is difficult to supplant the traditional way (i.e., cash or bank card) among older adults.

There is considerable evidence indicating that older adults face more difficulties than younger people when adopting technology (Barnard et al., 2013; Broady et al., 2010). According to Guo et al. (2013), compared with young people, older adults always lack education and experience with technology, which causes them to feel less competent and less in control when using a technology. Chang and Im's (2014) study aligned with this, which found that older people lack experience of computers which results in their

accessing of health information from the internet becoming difficult. In addition to the actual knowledge and experience of technology, a number of studies have highlighted that self-efficacy, which represents the perceived capacity and ability, also influences their technology usage.

Hawthorn (2007) in his study found that older adults may feel that they are too old and therefore inadequate and incapable of learning new technology. Tsai et al. (2020) point out that the difficulties suffered by older adults result in increased technology anxiety. Through empirical studies, it evidences that older adults experience greater anxiety and less comfort than younger people when adopting technology (Chang & Im, 2014; Guo et al., 2013; Wagner et al., 2010). Other researchers indicate that technology anxiety is more likely to negatively affect the attitude towards technology use, and its effects are especially strong when they process the adoption for the first time.

As a result, technology acceptance and adoption by the elderly has become an increasingly relevant field of study. Lots of researchers have put their effort into investigating the relationship between older adults and technology acceptance and identifying the reason behind their low acceptance.

2.4.1 Older adults' technology acceptance models

Some researchers argue that these generalized technology acceptance models lack the expression of older adults' technology acceptance behavior. They have addressed older adults' specific changes and heterogeneous characteristics. Some studies have focused on characterizing the nature and scope of the technology usage among generations (Marston et al., 2016). It is found that the investigation of the usage and adoption of gerontechnology by older adults is more sophisticated than by the younger generation because of their broader variety of socioeconomic status, education level, and physiological condition (González et al., 2012; Marquié et al., 2002). This sophistication poses challenges for the study of gerontechnology acceptance and usage.

The following are some models and theories that are commonly cited or integrated into older adults' technology acceptance studies.

(i) Senior technology acceptance model (STAM) (Chen & Chan, 2014a, 2014b)

Considering the unique characteristics and capabilities of the elderly, Chen and Chan (2014b) formulated a senior technology acceptance model by modifying the TAM and

UTAUT with the aim to investigate the technology acceptance by older adults in Hong Kong. This model, as shown in Figure 2.19, pointed out the lack of expression of older adults' technology acceptance behavior of prior technology acceptance models and adjusted it by adding age-related constructs including gerontechnology self-efficacy, facilitating conditions, and anxiety (Chen & Chan, 2014b). The researchers further extended the model by proposing that the physical, psychological, and social characteristics associated with aging affect older adults' interactions with technology, including social relationships, health conditions, attitude to life and satisfaction, cognitive ability, and physical functioning (Figure 2.20) (Chen & Chan, 2014a).

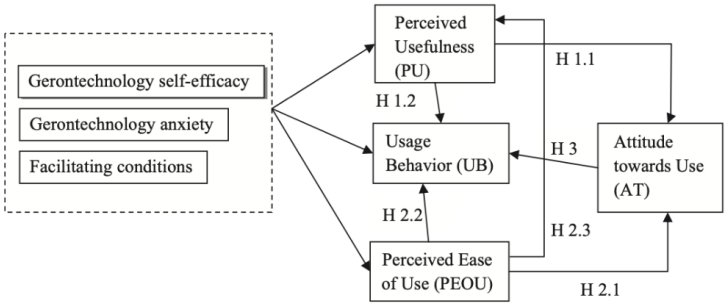

Figure 2.19 Senior technology acceptance model (Chen & Chan, 2014b)

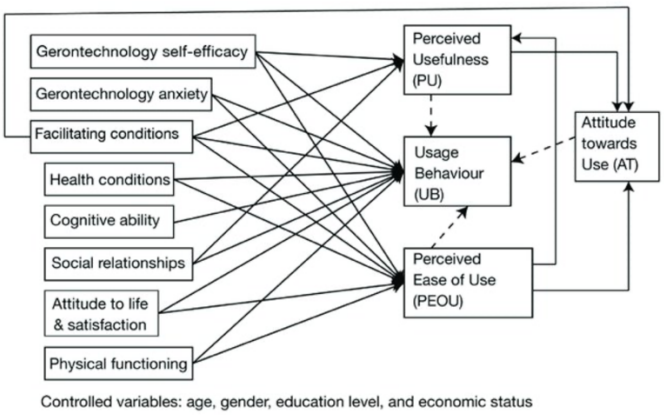

Figure 2.20 Extended senior technology acceptance model (Chen & Chan, 2014a)

(ii) Factors influencing the acceptance of technology for aging in place—model of pre-implementation acceptance (Peek et al., 2014)

To examine the key factors that affect the adoption and use of electronic technologies by older adults aging in place in a community dwelling, Peek et al. (2014) conducted a systematic review of papers related to the topic and sixteen out of 2,841 articles were

included. The included studies focused on investigating the factors that impact the willingness of older adults to use technology that supports independent living, as well as their perceptions and expectations of such technologies. The qualitative findings indicate that there are 27 factors that influence the acceptance of these technologies during the pre-implementation stage. The factors have been grouped into six themes, which are benefits expected of technology, concerns regarding technology, alternatives to technology, need for technology, social influence, and the characteristics of older adults (Figure 2.21).

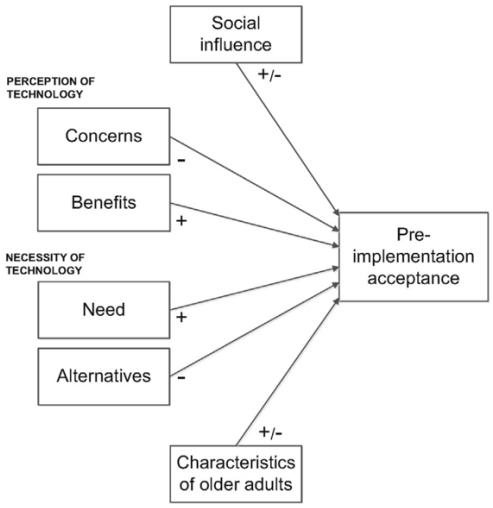

Figure 2.21 Model of pre-implementation acceptance (Peek et al., 2016)

(iii) Senior technology acceptance & adoption model (Renaud & van Biljon, 2008)

The senior technology acceptance model, as shown in Figure 2.22, was proposed by Renaud and van Biljon to specifically examine the factors influencing the adoption and use of technology by older adult users. This model builds upon the existing technology acceptance frameworks, but tailors the factors to the unique needs, context, and experiences of the aging population.

Inspired by the model proposed by Silverstone and Haddon (1996), they divide the technology adoption process into three phases: objectification, incorporation, and conversion/non-conversion. The objectification phase involves the older adults' initial perceptions, attitudes, and reactions towards the technology. Factors such as perceived usefulness, ease of use, and social influences play a key role in shaping the user's objectification of the technology. Once the technology is adopted, the incorporation phase examines how the older adult integrates it into their daily routines and lifestyle. Factors like the technology's compatibility with the user's needs and existing systems impact the incorporation process. Conversion/non-conversion is the final phase which determines

whether the older adult fully embraces the technology (conversion) or rejects it (non-conversion). Factors like the availability of support, the user's self-efficacy, and the overall experience with the technology influence this outcome.

Renaud and van Biljon's model captures the context of the elderly mobile phone user, and provides a comprehensive framework for understanding the unique technology acceptance journey of older adult users. This model can help inform the design, implementation, and support of technologies that enable aging in place for community-dwelling older adults.

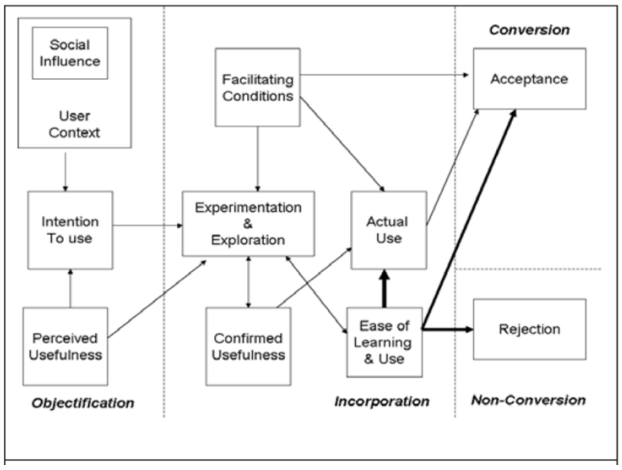

Figure 2.22 Senior technology acceptance & adoption model (Renaud & van Biljon, 2008)

2.4.2 Factors for older adults' technology acceptance

As technology acceptance is decided by the user's behavior and attitude to a large extent, it is important to reach some agreements on a comprehensive model that captures the key factors influencing the acceptance and adoption of technology. The aforementioned technology acceptance models for older adults have addressed their specific changes and heterogeneous characteristics. For instance, Chen and Chan (2014a, 2014b) taking older adults' biophysical and psychosocial changes into account, developed a new senior technology acceptance model (STAM), while Peek et al. (2014) focused on 'aging in place' characteristics, and through a systematic review, identified 27 factors in six themes affecting their technology usage. Renaud and van Biljon (2008) describe the older adults technology adoption process. Regardless of the sophisticated design of these models, discussions of technology acceptance and adoption behaviors among older adults extend beyond that; however, there is still no consensus on the factors influencing the technology acceptance of older people. As users' acceptance of technology is highly

determined by their attitude and behavior, several researchers (Chen & Chan, 2014a, 2014b; Macedo, 2017) advocate that to investigate the determinants for older adults' technology acceptance, further research is needed to provide a more comprehensive method.

Table 2.1 demonstrates the recent highly cited studies on older adults' technology acceptance. This is one of the first works summarizing and synthesizing the more acknowledged technology acceptance and adoption factors from different researchers by using different methods. It provides a clear list of influencing factors and allows us to gain a more holistic understanding of older adults' technology adoption.

In a comprehensive review, Lee and Coughlin (2015) examined 59 studies published since 1999 that explored factors influencing older adults' perceptions and decisions regarding the adoption of technology products and services. Through their analysis, the researchers identified ten key determinants that facilitate or hinder technology adoption among older populations which are value, usability, accessibility, affordability, social support, technical support, independence, experience, emotional enjoyment, and confidence. These ten factors cover a broader view of design considerations for older people than the generic technology acceptance models such as the TAM, UTAUT, and DOI, while the factors including value, usability, accessibility, and experience are closely linked with the perceived usefulness and ease of use in the TAM, effort expectancy and performance expectancy in UTAUT, and compatibility and complexity in DOI.

Table 2.1 Some popular studies discussing the factors influencing older adults' technology acceptance and adoption since 2010

	Cited Theory	Research Design	Context	Influencing factors discussed
Talukder et al. (2020)	UTAUT2	Empirical study-quantitative	Elderly's intention to adopt wearable healthcare technology	effort expectancy, performance expectancy, technology anxiety, facilitating conditions, social influence, resistance to change, and self-actualization, Hedonic Motivation, Functional Congruence
Vaziri et al. (2020)	TAM and SCT	Empirical study-both qualitative and quantitative	Use of sensor-based technologies for active and healthy aging	Technology experience, ease of use, usefulness, self-efficacy, barriers, reported physical activity per week, social support, health-related expectations, physical appearance-related expectations
Li et al. (2019)	TAM and UTAUT	Empirical study-quantitative	Wearable technologies for health monitoring for older adults	Facilitating conditions, compatibility, social influence, self-reported health conditions, perceived social risk, performance risk, perceived ease of use, perceived usefulness
Lee and Coughlin (2015)	TAM and DOI	Review study	Older adults' perceptions and decisions around the adoption and use of technology-enabled products and services	Value, usability, affordability, accessibility, technical support, social support, emotional enjoyment, independence, experience, and confidence
Chen and Chan (2014a, 2014b)	TAM, UTAUT, and STAM	Empirical study-quantitative	Gerontechnology, including housing and daily technology, communication technology, health technology and education and recreation technology	Gerontechnology self-efficacy, gerontechnology anxiety, facilitating conditions, self-reported health conditions, cognitive ability, social relationships, attitude to life and satisfaction, physical functioning, perceived usefulness, and perceived ease of use
Peek et al. (2014)	TAM and UTAUT	Systematic review	Focusing on electronic technologies that support aging in place by community-dwelling older adults	Concerns regarding technology, benefits expected of technology, need for technology, alternatives to technology, characteristics of older adults
Barnard et al. (2013)	UTAUT, DOI and STAM	Empirical study-qualitative	Mobile technologies to support walking and errors made during first use of a tablet computer	Performance expectancy, effort expectancy, social influence, facilitating conditions, relative advantage, compatibility, complexity, trialability, observability, transparency, affordance, feedback, and error recovery
Chan and Chen (2011)	TAM, TAM2, and UTAUT	Review study	Empirical studies on technology acceptance by older people	Perceived usefulness, perceived ease of use, personal characteristics (biophysical characteristics, sensation and perception, mobility, cognition, psychosocial characteristics, and social relationship)
Heerink et al. (2010)	TAM and UTAUT	Empirical study-three experimental studies	Social robots and assistive agents for eldercare	Anxiety, facilitating conditions, perceived adaptability, perceived enjoyment, perceived ease of use, perceived sociability, perceived usefulness, social influence, social presence, trust
Mitzner et al. (2010)	N/A	Empirical study-focus group	Use of and attitudes about technology in the context of their home, work, and healthcare	Convenience/inconvenience, feedback, features, complexity, reliability, serviceability, miscellaneous system characteristics, security, activity

Considering that the current study intended to identify the rationale behind product–service system (PSS) design for older adults adopting new technology, the terms ‘compatibility’ and ‘complexity’ in DOI are more aligned with this purpose. In addition to the factors listed above, Lee et al. (2013) suggest that factors such as service trust, system reliability, and lifestyle fit also play key roles in older adults’ technology adoption process, especially when accepting new technology. The researchers’ proposition has been further substantiated by findings from additional studies in this research domain. Li et al. (2019b) and Barnard et al. (2013) emphasize the crucial role of technology compatibility with older adults' established lifestyles and routines as a key determinant of adoption. Additionally, Heerink et al. (2010) highlighted the importance of trust in the technology, while Mitzner et al. (2010) noted the significance of system reliability as another influential factor. Expanding on the design considerations for technology products and services targeting older users, Mengoni and Peruzzini (2016) believe that information sharing with customers is an essential stage in user-centered design, which is necessary to promote the successful implementation of PSS.

2.5 Servitization

2.5.1 Definition of servitization

The notion of ‘servitization’ is usually traced back to the work of Vandermerwe and Rada (1988), in which they believed that services are beginning to dominate within the manufacturing industry and defined servitization as “the increased offering of fuller market packages or ‘bundles’ of customer focused combinations of goods, services, support, self-service and knowledge in order to add value to core product offerings.” In the discussion of servitization, the terminology ‘products’ and ‘services’ are the two elements that are unavoidable. The term ‘product’ can be understood as a tangible commodity manufactured to be sold. The term ‘service’ is an aligned concept with ‘product’ and defined based on what is not a product. It usually refers to an intangible offering.

Table 2.2 demonstrates other definitions of servitization in a broader literature. Based upon the concept of integrating products and services, most studies agree with Vandermerwe and Rada (1988) in their interpretation of servitization. Lewis et al. (2004) understand it in a slightly different way, incorporating the idea of product functionality into servitization. Baines et al. (2009) linked servitization with product–service system (PSS) research, defining servitization as the process of an organization shifting from

selling products to selling PSSs. Although these two terms emerged from different perspectives, they share a common concept that manufacturing corporates should increasingly focus on services to provide an integrated solution. As a result, 'servitization' and 'product–service system' are usually used interchangeably.

Table 2.2 Definitions of servitization

Author (Year)	Definition
Vandermerwe and Rada (1988)	The increased offering of fuller market packages or 'bundles' of customer focused combinations of goods, services, support, self-service and knowledge in order to add value to core product offerings.
Verstrepen et al. (1999)	Adding extra service components to core products.
Lewis et al. (2004)	Any strategy that seeks to change the way in which a product functionality is delivered to its markets.
Baines et al. (2009)	The innovation of an organizations capabilities and processes to better create mutual value through a shift from selling product to selling PSS.
Lightfoot et al. (2013)	It is about manufacturers increasingly offering services integrated with their products.
Kowalkowski et al. (2017)	The transformational processes whereby a company shifts from a product-centric to a service-centric business model and logic.
Khanra et al. (2021)	Manufacturing firms seek to generate additional financial value by shifting instead to offering their customers services associated with these products.

2.5.2 Evaluation and frameworks of servitization

In terms of its evaluation, although it is acknowledged that the term 'servitization' was coined by Vandermerwe and Rada in 1988, Davies (2004) argued that the pioneering applications of this kind of 'integrated solution' were enlightened in the 1960s with the emergence of "system selling" tactics. Unfortunately, servitization research appears to have attracted little attention from the mainstream of engineering and management before the 2000s (Baines et al., 2007; Neely, 2008; Tukker & Tischner, 2017). Clearly there are notable exceptions, but the evidence provided by these studies is relatively sparse and hard to substantiate the scale or range of servitization (Neely et al., 2011). Neely (2008) suggests that the development of ICT facilitates the progress of servitization. The advancement of technology allows many manufacturing organizations to develop new business models and to add services to products for the purpose of achieving competitive advantage. He has collected a large dataset on servitization of manufacturing from three time points: 2007, 2009, and 2011. According to statistics, 29.52% of publicly listed manufacturing firms in the OSIRIS database were classified as servitized, and the proportion increased to 30.10% (Neely et al., 2011). The famous examples include Rolls-Royce, IBM, and Xerox. It is notable that the services and providing methods offered by manufacturing firms are varied.

Therefore, they summarized the shift of services into five underlying trends as shown in Figure 2.23: 1) the shift from products to solutions; 2) outputs to outcomes; 3) transactions to relationships; 4) suppliers to network partners; and 5) elements to eco-systems.

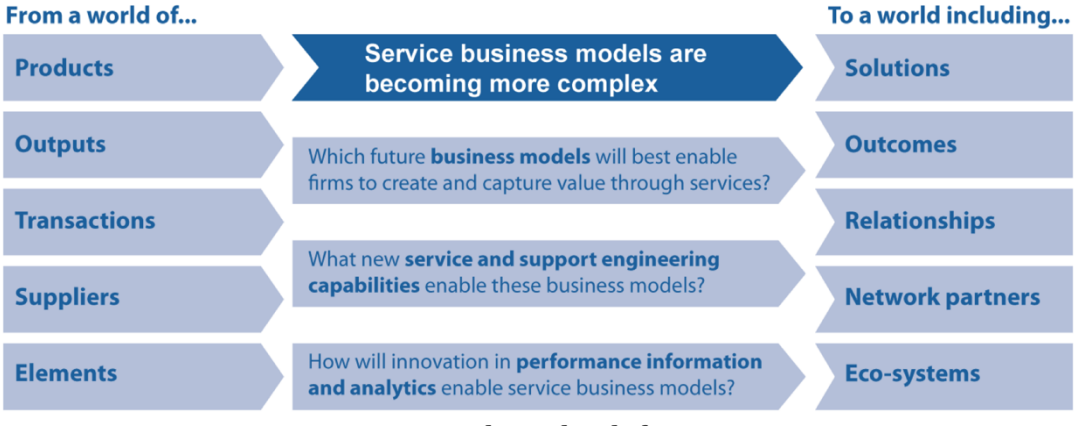

Figure 2.23 Summarizing the shift to services (Neely et al., 2011)

In addition to Neely, another group of scholars, led by Baines, have raised the popularity of servitization and the recognition of it in the industry and academia through two reviews (Baines et al., 2007, 2009). As aforementioned, this group of scholars demonstrated the high similarity between product–service systems and servitization. Therefore, servitization became synonymous with firms that shift from selling products or products and basic services to providing PSSs in the following years (Rabetino et al., 2018), which led to a blurring of the boundaries between products and services. Based on the different levels of service integration, Baines and Lightfoot (2013) suggested to classify it into three levels according to customer propositions: 1) base services, where the customers 'want to do it themselves' and only rely on the manufacturer to provide the service such as question answering, spare part changes, and guarantees; 2) intermediate services, where the customers 'want us to do it with them,' and they will carry out some work themselves but engage the manufacturer for support, such as adjustments and repairs, in-field service, and initial stage training; and 3) advanced services, where the customers 'want us to do it for them,' and they contract the service offered through the whole use life of the product and let the manufacturer take care of everything for them as shown in Figure 2.24.

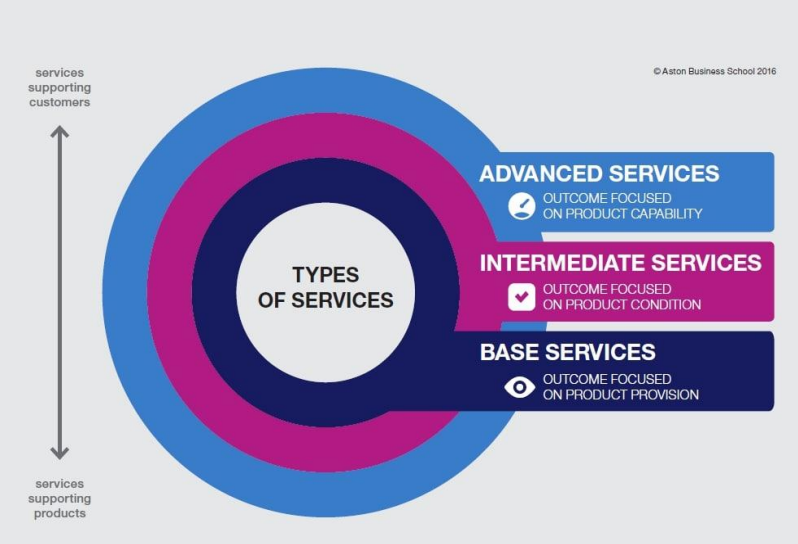

Figure 2.24 Three levels of services (Baines & Lightfoot, 2013)

In recent years, the strong customer orientation as a key characteristic of servitization has been frequently addressed by researchers (Ruiz-Alba et al., 2019), which means that customers not only receive a homogeneous product but also a tailored 'solution.' Previous studies have proved that the customer service level can affect customer satisfaction. Providing a better customer service can have a positive influence (Afthanorhan et al., 2019; Prakash & Mohanty, 2013). According to Fargnoli et al. (2019), there is a need for designing different modular units of services that can be mixed and matched to meet different customer and market needs. For the older customer group, the service design should be more adjustable, as they are more varied in reliance, ethnicity, well-being, physical condition, and financial status.

In this study, servitization is understood from two points of view. Firstly, it is considered as a shift from solely products to product–service systems. Secondly, it is regarded as a shift towards a better customer understanding with value added from the customer perspective.

2.5.3 Product–service system

As mentioned above, product–service systems and servitization are two closely related concepts. Traditionally, people always considered products and services separately. Recently, products and services are more and more integrated to jointly fulfill specific customer needs, which forms the concept of 'servitization' of products and 'productization' of services (Baines et al., 2007). Morelli (2003) regards 'servitization' to derive from the evolution of product identity where the material content is no longer seen as separate from

the service system. Conversely, ‘productization’ arises from the evolution of a service, where additional product features or a new service component are marketed as a product. In some studies, it is also called ‘deservitization’ (Kowalkowski et al., 2017). Figure 2.25 demonstrates the trends of convergence of products and services into a single PSS. Nevertheless, research of PSSs has focused almost entirely on the ‘servitization of products’ process, and the concept of ‘dematerialization’ is often stated as an important aim by many PSS practitioners and researchers.

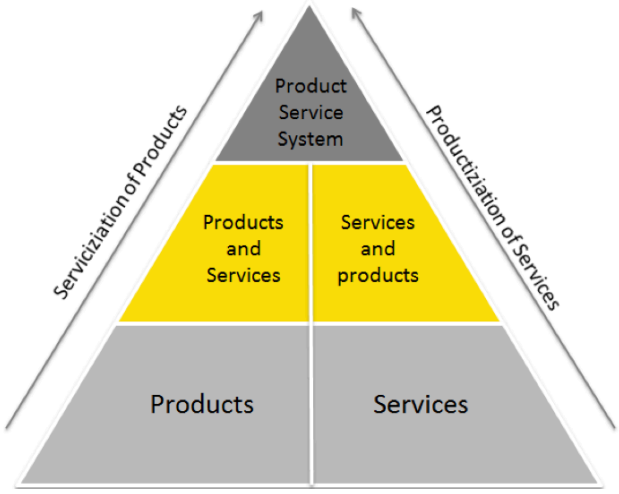

Figure 2.25 Evolution of the product–service system concept (Morelli, 2003)

The term ‘PSS’ was first formally introduced by Goedkoop et al. (1999), defining it as ‘a marketable set of products and services capable of jointly fulfilling a user’s need.’ They proposed the PSS as an alternative to adding value by integrating products and services, thus realizing economic value and minimizing environmental damage simultaneously. Mont (2002) redefined a PSS by involving environmental improvement, as ‘a system of product, services, supporting networks and infrastructure that is designed to be competitive, satisfy customer needs and have a lower environmental impact than traditional business models.’ Manzini and Vezzoli (2003), from the market perspective, regard a PSS as an innovation strategy for the company, shifting the business focus from designing and selling physical products only to designing and selling the system of product and service and it considered a PSS as an ultimate goal for businesses. This shift represents a marked departure from the traditional linear consumption model of ‘take, make, dispose,’ that promote excessive material possession, unchecked production, and environmental degradation. In contrast, contemporary consumption paradigms prioritize the principles of ‘reduce, reuse, recycle, and recover,’ emphasizing waste minimization, extended product

lifespans, and resource regeneration (Corvellec & Stål, 2017). It is an innovative model not only enhances user experiences but also promotes environmental sustainability and circularity (Barquet et al., 2016).

Figure 2.26 describes the transition from a product to a product–service system. A common manufacturer generates value solely from the product itself and each incidental service would result in additional costs. To improve competitive advantage, well-designed and well-selected services are implemented to enrich the total offering, and in the end, the product and services are integrated into a product–service system resulting in unique value and competitiveness (Kryvinska et al., 2014). Some researchers have argued that the difference between a PSS and servitization is that the concept of servitization goes beyond the idea of a PSS, as it represents a more profound transformation where a manufacturing firm ultimately transitions into a service provider. Consequently, as stated above, Baines et al. (2009) suggested to refine the definition of servitization to better incorporate the PSS concepts, by defining servitization as 'the innovation of an organization's capabilities and processes to better create mutual value through a shift from selling products to selling PSS.'

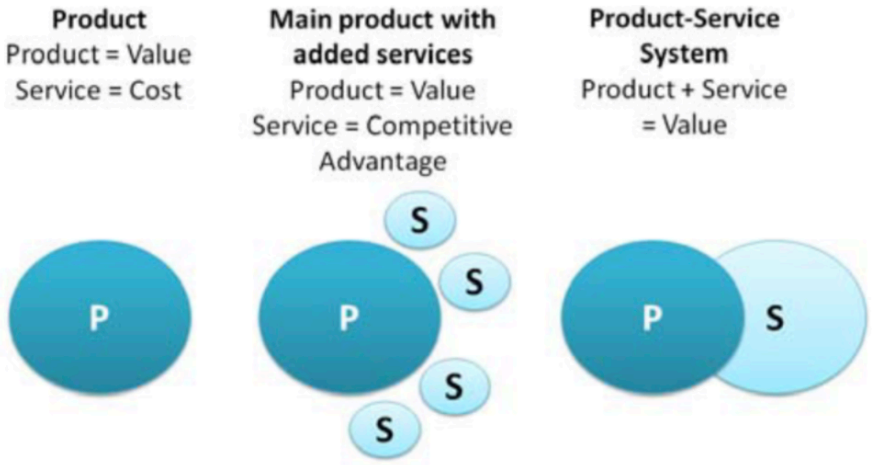

Figure 2.26 Transition from a product to a PSS (Kryvinska et al., 2014)

The ratio between the product and service components in a PSS varies from case to case and is based on the different emphasis. A PSS has been commonly classified into three divisions, which are product-oriented PSSs, use-oriented PSSs, and result-oriented PSSs. Tukker (2004) further subdivided these three categories of PSS into eight types according to its economic and environmental characteristics. Figure 2.27 lists eight types of PSS which are product-oriented services: advice and consultancy and product-related services; use-oriented services: product renting or sharing, product lease, and product pooling; and result-oriented services: pay per service unit and activity management/outsourcing. From the first to the last, their dependence on the product as the

core component of the PSS decreases, and the need for service features increases. The provider has more and more freedom to satisfy the true final needs of customers, while the need of customers is more and more abstract.

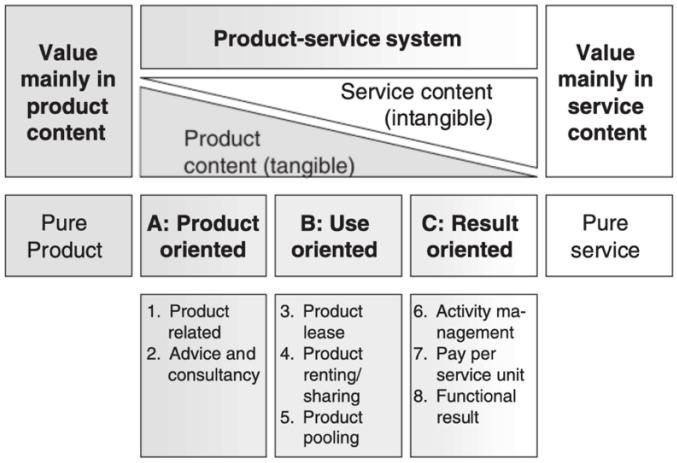

Figure 2.27 Main and subcategories of PSSs (Tukker, 2004)

2.5.4 Benefits and challenges for servitization

Owing to servitization accelerating the integration of products and services, it potentially brings changes to the production and consumption patterns. As researchers have gained a deeper understanding of the conceptual foundations underlying the development and implementation of a servitization strategy, the trade-offs between the benefits and challenges of servitization are becoming more apparent (Khanra et al., 2021). As addressed by most researchers, there are three sets of benefits generated from servitization transformation, which are for servitization providers, for customers, and for society.

The benefits for servitization providers have been widely discussed by researchers as these are the factors that drive them to pursue a servitization strategy. Firstly, gaining a competitive advantage has been regarded by many providers as the most attractive feature of servitization. Through servitization, these use of service elements can differentiate their products and services setting with their competitors and therefore offer important competitive opportunities. This kind of competitive advantage is harder to imitate than pure products owing to the high inimitability of intangible services. Secondly, this pattern may also avoid price-based competition because providers are more focused on the total cost of ownership. Additionally, in the service-dominant logic perspective of marketing (Vargo & Lusch, 2004), customer value is considered as a fundamental source of

competitive advantage. In this context, the idea is that service provision beyond a product itself is the basis for economic exchange, and the customer as a co-creator of value is an important premise.

On the other hand, from the customer side, the increased customer value and closer customer relationship generated by more direct contact with servitization providers result in more customization and higher quality. It offers customers a greater diversity of choices in the market, such as different product use schemes and various payment schemes; therefore, customers can obtain added value through more customized offers with a higher quality. Moreover, customers may be released from the responsibility for the product over its entire product life span. Baines et al. (2007) argued that services added to products deliver new functionality to the total solution, which transfers administrative or monitoring tasks from customers back to the manufacturer.

For society, servitization is regarded by many researchers as a way to enhance the sustainability, particularly in PSS studies, since it allows for decoupling economic growth and material input. From a servitization perspective, the provider has to realign the relationship between customers and suppliers by considering the total product's life cycle cost (UNEP, 2015). In this way, customers receive the full benefit of the product and service combination, and thereby, providers are no longer interested in maximizing production and sales. Instead, they are more concentrated on resources and energy consumption during the product's life cycle and extension of the product lifespan which leads to an economically and environmentally preferable outcome (Brandstotter et al., 2003).

According to the comprehensive reviews of servitization (i.e., product–service system) conducted by Annarelli et al. (2016), Lightfoot et al. (2013), and Martinez et al. (2010), there are two major challenges related to servitization found in the literature. One of the major challenges is strong manufacturing capability. Conventional manufacturers have strong manufacturing capabilities in terms of research and development (R&D), technological engineering as well as production. To facilitate the servitization of products, manufacturers are putting great efforts into how new, emerging, and advanced technologies can be integrated into products or services, instead of providing total solutions. This may inhibit their transformation into service-centric manufacturers that are able to offer integrated products and services. Another major challenge is ineffective responsiveness to customer needs. The design processes of products and services are required to be aligned for the provision of integrated product–service offerings, in

accordance with user needs. The existing methods provide reactive feedback based on the comments provided by users after using the products instead of a proactive manner of responding to user needs in the early stages of integrated product–service development. To cope with the challenges, it is necessary to help the manufacturers find ways to appropriately integrate products and services and seize the essence of customer needs proactively.

2.6 Gamification

2.6.1 Definition of gamification

Gamification, with its potentials for influencing and motivating people, is sought after in the business and service marketing field (Hamari et al., 2014). This term originated in the digital media industry in 2008 by Brett Terrill as 'bringing gaming mechanics to other online domains in order to promote engagement,' and it entered more widespread adoption in 2010 (Huotari & Hamari, 2017). Gamification has developed and evolved within the rich interactive trends of games and interaction design; therefore, there are several overlapping concepts. To have a deep understanding of gamification, it is necessary to clarify its related terms.

As shown in Figure 2.28, the definition from Deterding et al. (2011) distinguishes gamification from playful design, serious games, and toys based on the two dimensions of playing & gaming and whole & parts. Firstly, although 'game' and 'play' are two close terms, there is a difference. This distinction is usually traced back to Caillois' concept of *paidia* and *ludus. Paidia* (playing) describes more free-form, expressive, and improvisational behaviors and meanings, and on the other hand, *ludus* (gaming) captures rule-based and goal-oriented playing. Consequently, the introduction of 'gamefulness' as a complement to 'playfulness' distinguishes gamification from playful interaction and playful design. In terms of the concept of 'whole' and 'parts,' it distinguishes the use of a complete game with applications of game elements. A serious game describes a full-fledged game for non-entertainment purposes, and gamified design only encompasses game elements. As a result, gamification is defined as 'the use of game design elements in non-game context' by Deterding et al. (2011). Similarly, Zichermann, as a leading researcher of the gamification industry, described gamification as a tool to complement efforts by integrating game-like elements and mechanics into the branding initiatives (Zichermann & Linder, 2010).

As games are provided in increasing numbers as services to customers, they are becoming popular in the service marketing field. From the service perceptive, Huotari and Hamari (2012) define gamification with a different approach, which refers to gamification as 'a process of enhancing a service with affordances for gameful experiences in order to support user's overall value creation.' This definition highlights that the purpose of gamification is to generate the experience instead of the method. They argued that basically, game-specific elements do not automatically create a gamified experience. Gamification does not occur solely through any particular element either. They use 'affordances' to substitute 'elements,' which refers to 'actionable properties between an object and an actor.' Affordances do not force users to act on them, or even not necessarily interpret them in the way the designer does. Rather, they provide the possibility for gamified experience and behavior to occur. This study follows this definition to interpret gamification, i.e., regarding gamification as a servitization strategy.

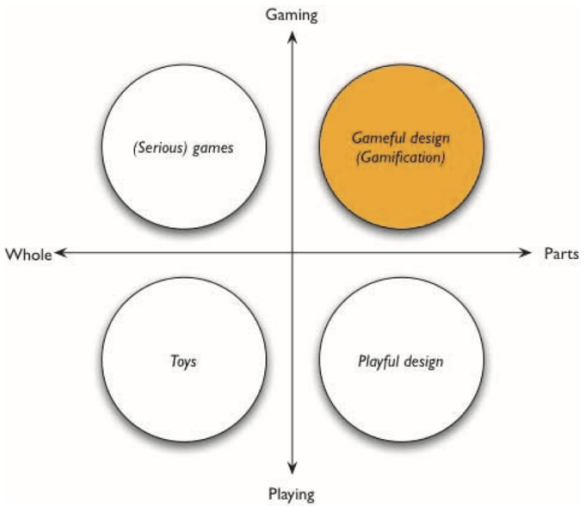

Figure 2.28 Gamification concept with game and play, whole and parts (Deterding et al., 2011)

From its definitions, most researchers agree that gamification strategies can generate positive effects for the users (Baptista & Oliveira, 2017; van der Heide & Želinský, 2021); however, there are also some studies which have reported inconclusive, or even negative outcomes. For instance, a study conducted by Çera et al. (2020) indicated an insignificant effect of gamification on users' intention to use m-banking. In addition to e-finance, the mixed results commonly happened in other fields as well, and this issue has been widely acknowledged by critical scholars. Koivisto and Hamari (2019) explained that many

gamification applications directly adopt a gaming design in ‘non-game’ contexts, which lacks contextual distinctiveness and theoretical consideration.

2.6.2 Theories in gamification

According to Krath et al. (2021), the theoretical foundations for gamification studies mainly originate from three research streams, which are social psychology, cognitive psychology, and human–computer interaction. Some commonly used models and frameworks for outlining theoretical foundations and gamification systems design and analysis are described and elaborated as follows:

(i) Mechanics, Dynamics, and Aesthetics (MDA)

A series of papers explore the design of gamification by cataloging and documenting gamification elements. The MDA framework is one of the most frequently used design frameworks, which identified mechanics, dynamics, and aesthetics as three levels to conceptualize the dynamic behavior of game systems (Hunicke et al., 2004).

Mechanics describes ‘the specific components of the game, at the data representation and algorithms level.’ They do not change from one player to the next. Dynamics describes ‘the behaviors that act on the run-time of mechanics on player input and each other’s outputs over time.’ Therefore, they shape the reasons behind users’ motivated behavior towards game mechanics. Aesthetics describes ‘the desirable emotional responses evoked in player when he/she interacts with the game system.’ Aesthetics evokes people’s emotional responses when they interact with the system, such as fun and surprise, that enhances their motivation and engagement (Hunicke et al., 2004). By moving among the three levels, we can conceptualize the dynamic behavior of game systems. This framework allows us to draw explicit reasons about specific design goals and to predict how changes will impact each aspect of the framework and the resulting implementations.

(ii) Self-determination theory

Motivation theories have been widely applied to understand gamification rationale and gamified systems commonly link motivation theories with game elements to create motivational features. Among them, self-determination theory (SDT) has been the most cited. It postulates autonomy, competence, and relatedness as three main sources of intrinsic motivation (Ryan & Deci, 2002). Studies conclude that game mechanics can

partially or fully address people's psychological needs identified in SDT, such as the feeling of competence can be fostered by achievements and badges, autonomy can be fulfilled by profiles and customization, and relatedness can be enhanced through teamwork and social networking (Xi & Hamari, 2019).

(iii) Flow theory

Flow theory is also a popular theory in design, explaining or evaluating the gamified interventions. It is focused on intrinsic strengths and grounded in the positive psychology notion. Seligman and Csikszentmihalyi (2000) defined it as 'the study of positive emotion, positive character, and positive institutions.' Flow is an optimum experience where individuals achieve a completely absorbed and concentrated state. As shown in Figure 2.29, to reach the optimal experience, there should be a balance between a person's perceived challenges and skills. When a task is too difficult, and a person is not equipped with the level of skills for this challenge, people may feel anxious and restless. When a task is too easy and requires a lower level of skill, people may become bored. Changing the difficulty is desirable in flow regions, where one is neither under nor over challenged.

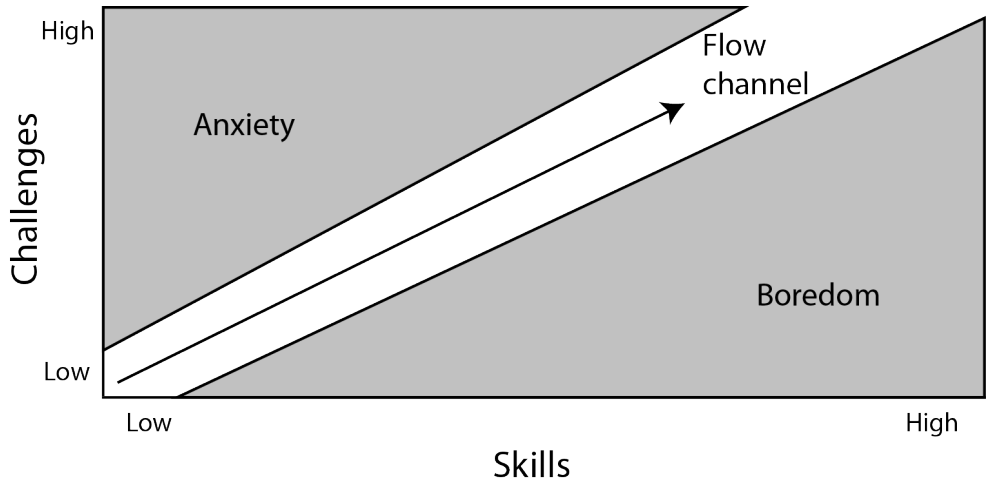

Figure 2.29 Flow theory (Seligman & Csikszentmihalyi, 2000)

In addition, theories related to technology acceptance and adoption, including the technology acceptance model, social cognitive theory, theory of reasoned action, theory of planned behavior, and the motivational model have also been used to explain the user behavior and psychological mechanism in gamification applications (Krath et al., 2021). These theories commonly serve as a basis to assess the gamification impact on behavioral intentions, such as making a purchase (Bittner & Shipper, 2014), and the intention to adopt a technology (Rai & Beck, 2017). They are also used to evaluate the performance of

gamification interventions, such as whether gamification may generate positive attitudes or behavioral intention to use (Vanduhe et al., 2020).

Despite the recognition of design and motivation theories in gamification, some researchers have argued that many pervious gamification studies lack a theoretical foundation (Huang & Hew, 2018; Sailer & Homner, 2020). After reviewing 769 gamification papers in different disciplines, Seaborn and Fels (2015) found that the majority of them were not grounded in theory. Huang and Hew (2018) pointed out two main problems of theories' use in current gamification research: firstly, many studies rely on these generalized theories regardless of the contextual difference or blend popularized versions of these theories with other models to create untested 'home-made' motivation models; secondly, some researchers merely propose some gamification design framework without tests and a theoretical basis. To propose a successful design of a gamified system, using conceptual propositions as a basis is critical, and insufficient knowledge of mechanisms by which gamification produces their effects may lead to an undesired outcome.

2.6.3 Gamification for older adults

At the current stage, gamification studies with older adults are given limited attention (Koivisto & Malik, 2020). Some have argued that compared with young adults, older people perceive less understandability and benefit less from existing gamification initiatives (Koivisto & Hamari, 2014). However, given the fact that most current gamification designs, models, or implementations are basically aimed at young people or its default target users are young people, it cannot truly examine the effectiveness of gamification for older adults (White et al., 2022). Some researchers have argued that gamification implementations greatly depend on the context as well as the target user; therefore, generalizing the results from one setting to a different context can be challenging (Deterding, 2015; Koivisto & Hamari, 2014). This is particularly true when it applies for older adults due to the heterogeneous features and technology usage difference raised by age. Older adults are differentiated from the young generation in many aspects, such as their physical and mental condition, life experience, goals and priorities, source of fun, ability with games, preference for game characters, as well as attitude regarding the activities to be gamified (Altmeyer et al., 2018; Gerling et al., 2011, 2012). As a result, further research on the elderly and gamification is needed and should be based on sufficient

considerations of older adults' factors (Wong et al., 2021).

Unfortunately, studies on gamification in relation to older adults are few and they almost all focus on the health domain (Boot et al., 2016; Koivisto & Malik, 2020). Far too little is known about how older adults experience gamification and whether gamification can improve motivation and knowledge in other domains. Given the demographic shift and digital divide, the technological needs, opportunities, and challenges extend to domains beyond health (Sun et al., 2017). As a result, the potential of gamification for increasing older adults' acceptance and adoption with emerging technologies is awaited.

2.7 Summary

Based on the discussion of the existing literature, the progress and limitations of population aging, gerontechnology, technology acceptance, servitization, and gamification domains in their current stage have been revealed as shown in Table 2.3.

The unprecedented demographic shift towards an aging population has presented a formidable challenge to academics, industry, government, and all those who have the responsibility for promoting a more inclusive society, but it also brings opportunities. Technologies can play a key role in achieving positive outcomes in 'aging in place', while their utilization remains limited. Gerontechnology, as an interdisciplinary study with technology and gerontology, could play a critical role in preparing for the social changes that accompany population aging. It is an emerging field of research that has garnered attention from both academia and industry, resulting in the emergence of a range of technology products tailored to the needs of older adults. Meanwhile, currently, most gerontechnological products have not achieved widespread adoption, and their related services have been overlooked. The research on technology acceptance is used to explain users' technology acceptance and adoption behaviors. Varied famous models and frameworks have been constructed such as the TAM and UTAUT, while the commonly used models have been deemed as lacking expression of older adults' characteristics. Therefore, several specified models for older adults have been developed. Nevertheless, there is still no consensus on the list of variables that influence older adults' technology usage. As a result, further study is needed to develop a comprehensive model for understanding older adults' technology acceptance and adoption behaviors.

The servitization concept accelerates the integration of products and services and has been considered as a direction to assist older people's technology usage. It brings

substantial benefits to the organization, customers, and society but barriers need to be considered when transforming from the traditional business model. There are two major challenges for manufacturers: firstly, most of them have a strong focus on R&D instead of product and service integration; secondly, many of them fail to proactively meet customer needs.

Gamification as a means of motivating people could be integrated into the servitization strategy to facilitate older adults' technology adoption progress. Substantial empirical studies have been done to examine the motivating effect of gamification, while mixed results were found in pervious works. This phenomenon indicates that one research gap in this field is that some gamification studies lack of methodological rigor. Additionally, studies on gamification applications for older adults are limited and most of them focus on physical health and cognitive psychological areas. Hence, an opportunity arises for research to investigate the efficacy of gamification strategies targeted towards older adults, with the objective of bridging the digital divide among this demographic and expanding the research scope of gamification user profiles.

Table 2.3 Summary on literature review and research gaps

Research field	**Prior literature**	**Research gaps**
Population aging	• Population aging in the world • Hong Kong faces more severe issue	• Challenges on responding the continuing rise aging population • Technology for 'aging in place'
Gerontechnology	Emerging field that has garnered attention from both academia and industry	• Many gerontechnological products are not widespread • Related services have been overlooked
Technology acceptance and adoption	• Varied famous models and frameworks • TAM and UTAUT are most commonly used models	• Commonly used models lack expression on older adult's characteristic • No consent on the list of variables influence older adults' technology usage
Product-service system and servitization	Many manufacturing companies add services into product for competitive advantage	• Strong focus on R&D instead of product and service integration • Fail to proactively meet customer needs
Gamification	Widely discussed in varied domains, e.g. education, business, computer science	• Lack of theoretical basis and context consideration • Studies on older adults are limited

Chapter 3 A Study of Gerontechnology Development and Its Acceptance by Older Adults in Hong Kong

As delineated in the literature review, population aging poses great challenges to our society, and technology progress brings opportunities to cope with this social shifting. However, as a promising leverage, technology is not well accepted and diffused among older adults. Addressing the low technology adoption among the elderly, gain a comprehensive understanding of the technology development targeted at older adults as well as the technology usage among them is prioritized. As a result, the researcher analyzed this issue from both macro and micro perspectives. The macro analysis was conducted through the method of document analysis, aiming to examine the recent progress of gerontechnology products and services, the underlying technology and ongoing research, and the social factors driving this field. Based on the findings, a roadmap was formulated to offer valuable insights into the future trends and challenges in the development of gerontechnology. The micro analysis was conducted from older adults' perspective through an empirical investigation into gerontechnology acceptance and usage conditions as well as its servitization progress.

The linkage between macro analysis and micro analysis lies in their complementary roles in providing a comprehensive understanding of technology products and services development for older adults. The macro analysis offers a broad, strategic perspective, while the micro analysis provides detailed, user-centered insights. Together, they create a robust foundation for developing effective, user-friendly gerontechnology solutions that address the needs and preferences of older adults. This integrated approach ensures that both the overarching trends and the individual experiences are considered, leading to more informed and impactful outcomes in the field of gerontechnology.

3.1 Macro analysis of ICT-oriented products and services development for older adults in Hong Kong: a roadmap for research and practice

Through the literature review, a general understanding of research progress and limitations of population aging as well as gerontechnology products and services have been captured. However, to fully understand and address the complex challenges and opportunities in the development of technological products and services for older adults, in addition to academic output, government policy, social needs, and market focuses also play critical roles. This study conducted a comprehensive review of the development of the gerontechnology field, which included not only research papers but also other relevant sources of information such as news articles, government reports, market analysis, industrial reports, business websites, and surveys. It aimed to explore how the social drivers, supporting technology, and R&D affect the development of gerontechnology products and services. Roadmapping was employed as the research method in this study to provide the overview and vision of gerontechnology products and services for older adults in Hong Kong. In contrast to a typical literature-based study that focuses on summarizing and synthesizing previous research (Snyder, 2019), this study not only reviewed the recent progress in gerontechnology but also provides insight into its future trends and challenges.

Among different gerontechnology categories, information and communication technology (ICT), as one of the critical means of economic development and human social and communication links, was selected as the case to be investigated. With the outbreak of COVID-19, ICT became the most important technology due to the restrictions on direct social contact (Yang et al., 2020). People had to rely more on digital means to accomplish things and communicate in society. At the same time, this social change exposes barriers to and problems with older adults' ICT usage. Nevertheless, it forced older adults to actively or passively learn technologies in order to address their living demands, such as contacting friends or relatives through video communication.

Prior studies have acknowledged many advantages of ICT implemented for older people, including benefits in relation to social and self-understanding (e.g., access to news and health tracking), task-oriented goals (e.g., online shopping, e-financing, and takeaway services), and interaction benefits (e.g., increased connection with society) (Selwyn, 2004). Although the importance and potential benefits of ICT for elderly people have been recognized, this group of people still exhibits lower levels of internet and electronic devices use compared with other groups of people (Smith, 2014). Some researchers indicate a

vigorous increase in older adults' ICT usage in recent years. Nevertheless, the ICT adoption rates of elderly is unlikely to match the level of younger people. Consequently, research about ICT for older adults has become a relevant field of study.

Instead of investigating products and services respectively, this study discusses them in a product-service system (PSS). In the gerontechnology field, the product-service system (PSS) concept is more or less integrated into ICT products or services. It could provide a leverage for ICT providers to increase older adults' acceptance of new technology. Many ICT providers recognized the advantages of applying PSS instead of providing solely either a product or a service for improving customer satisfaction and their competitiveness (Tukker, 2004). This is particularly true for those whose target customers including older people or whose products are specialized for the older customer. A key characteristic of PSS is its customized orientation (Mont, 2002), which is inherently better matched with the features of older adults, as they are more variable in dependency, ethnicity, well-being, physical condition, and financial status (Numata et al., 2016). However, the current PSS for aging-related ICT spans fragmented and diverse spectrums of research and practice. There is therefore a huge potential for the future development of ICT-oriented PSS, but the future trends remain uncertain.

3.1.1 Overview of the Roadmap

As mentioned by Galvin (1998), roadmapping is "an extended look at the future of a chosen field of inquiry composed from the collective knowledge and imagination of the brightest drivers of change in that field." This concept was first proposed by Motorola in the 1970s by providing 10-year forecasting of its product and technology development, which synthesized the main elements of the company's strategic plan into a clear visual demonstration (Phaal et al., 2004b; Willyard & McClees, 1987). Nowadays, the roadmap technique is widely used in various industries (e.g., mining (Amadi-Echendu et al., 2011); the energy sector (Jeffrey et al., 2013); the construction industry (Siebelink et al., 2016); and logistics companies (Cheng et al., 2021)), and several roadmaps in the ICT field have been developed (Abbasi et al., 2017; Cheng et al., 2014; Man et al., 2015), but roadmaps focused on technology for older adults are rare. In fact, there is no specific method for roadmap development, and the approach has been adapted to support various purposes, with differing scopes and levels of generality (Camarinha-Matos & Afsarmanesh, 2004).

In this study, the idea of technology roadmapping was applied with the aim of capturing the current progress, future trends, and challenges of ICT-oriented PSS development for the aging population. Technology roadmapping enables the exploration of the future trends of products/services/technologies/tools with dynamic linkages between changing environments, industrial directions, and technological resources (Phaal et al., 2004a). The technology roadmap approach can be regarded as extracting key themes from the strategic change and strategic technology planning literature, by combining a layered structure with the time dimension (Phaal et al., 2004b). The most general and flexible approach is illustrated in Figure 3.1, enabling the various perspectives and functions within a context to be aligned, and establishing a structured framework to address three fundamental questions: where do we want to go? where are we now? and how can we get there? (Phaal et al., 2008).

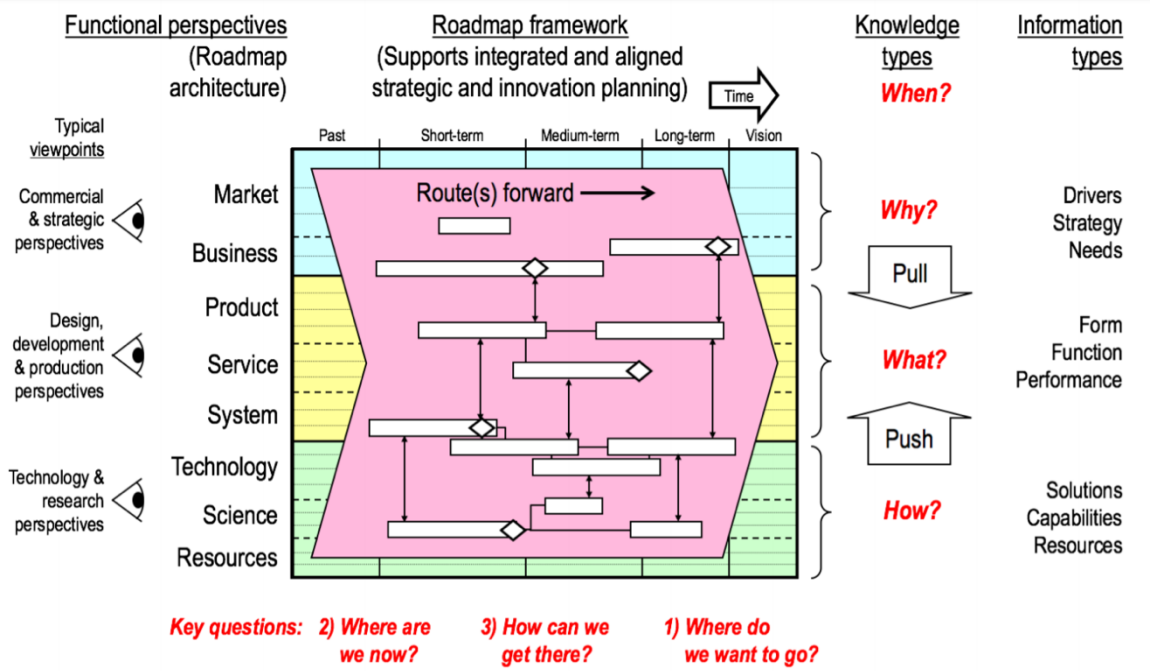

Figure. 3.1 A general structure of a technology roadmap (Adapted from Phaal et al. (2008))

3.1.2 Research process

As forecasting the future and investigating the interdependencies among all driving forces associated with a targeted field is difficult in nature, a profound roadmap requires comprehensive consideration of a variety of factors from different resources in the field.

In order to appropriately integrate the various contributions into the right context, it is necessary to follow a systematic process (Camarinha-Matos et al., 2013). Two experts on technology roadmapping were involved in the roadmap formulation. Their expertise provides a strong foundation in the development process. The combination of expertise, alignment, and a structured approach ensured that subjectivity and consensus challenges were effectively managed. In fact, there is no commonly used procedures for building a technology roadmap. However, by comparing and contrasting various studies of technology roadmap development (Camarinha-Matos et al., 2013; Park et al., 2018), this study has identified the following three phases, combining six steps, as shown in Figure 3.2. The first phase is to generate the basic idea of the research. After establishing the goals of the study, the basic research has been done to define the roadmap structure (i.e., technology roadmap) and the main themes to be investigated have been set (i.e., aging problems in Hong Kong, social need and drivers, ICT in aging, PSS in ICT, and ICT technology and resource). Along with the main themes, the key stakeholders who play critical roles in determining the direction of future development need to be identified (Cheng et al., 2021). In this study, older adults, government, industry, the academy, and caregivers are identified as the key stakeholders that influence ICT-oriented PSS development for the elderly.

As a result, data were collected using online desktop research techniques based on the main identified themes from the perspectives of these five key stakeholder groups in the second phase. To obtain inclusive understanding, multiple types of data-sources were collected, including research papers, conference proceedings, government reports, government websites, industrial reports, business websites, surveys, and news media. Based on these research materials, the future trends were captured and articulated through vision, scenario, and challenge analysis. In the third phase, a roadmap was drawn based on the results identified by the data analysis.

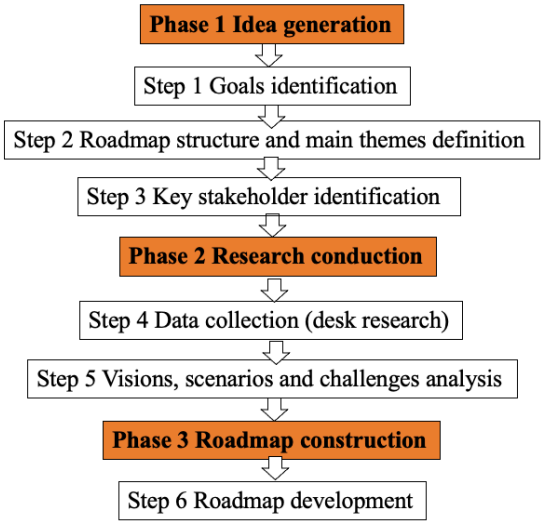

Figure 3.2 Research Process

3.1.3 Results and Discussion

3.1.3.1 Social Needs and Drivers

(i) Aging in Hong Kong

According to the Hong Kong Census and Statistics Department (2020b), the number of Hong Kong citizens aged above 65 years old reached 1.32 million in 2019, accounting for 18.4% of the total population. In 2022, the proportion has reached 20.8% (1.5 million), which indicates that Hong Kong's transition to the 'super-aged society' is imminent. The growth rate of the elderly population will increase at a much faster pace in the coming decades, with a speed even more dramatic than in other developed economies, such as Japan. It is projected the percentage of the population comprised of the elderly will increase to 26.0% by 2029 (Hong Kong Census and Statistics Department, 2020b).

With the ascending older population, the most direct impact will be the rise of the old-age dependency ratio, which means that there will be increased strain on those in the labor force to support those who are economically dependent (Hong Kong Census and Statistics Department, 2016). Associated with this change, the number of care institutions will increase to cope with the increasing number of elderly people, thereby leading to increased demand for caregivers. However, it is difficult to retain more caregivers due to the shortage of labor force in the market and this shortage of caregivers might become serious from the 2030s onwards (Hong Kong Census and Statistics Department, 2020b). On the other hand, with technology development and accumulated medical experience, Hong Kong enjoys the

longest life expectancy in the world as aforementioned (Hong Kong Census and Statistics Department, 2020a).

(ii) Older Adults Needs

As society evolves, older adults' needs and demands will change accordingly. The increasing dependency ratio leads to a change in living arrangements. According to the United Nations, in the developed regions, the proportion of older adults living with only a spouse is the most common living arrangement and living alone ranked second, while living with an extended family is becoming less common (United Nations, 2020). Along with it, there is a phenomenon of 'aging in place', where the older people are more willing to stay at their home instead of living in the nursing house in their retired life due to the feeling of comfort and convenience when living in a familiar environment. Some gerontologists found that in the current stage, the majority of the older population is able-bodied, if they have the opportunity to live actively and independently, they are able to generate more value to our society, such as their knowledge and experience (Au et al., 2021). Researchers further indicate that, during the next decade, the new generation of older people will have a better financial and education level. As a result, they are more likely to have higher demands of life quality (Ren, 2023).

(iii) Government Drivers

As a key stakeholder, the government plays a critical role to strategically channel ICT-oriented PSS development for the elderly. Recognizing the severity of the aging problem in Hong Kong, the government has conducted a variety of thematic research initiatives to understand the condition of older people. From the thematic household report on personal computer and internet penetration, the low-level usage of computer and internet for older people is acknowledged (Hong Kong Census and Statistics Department, 2023c). As a result, the Hong Kong government has been endeavoring to implement varied initiatives to facilitate wider adoption of ICT for older people over the years. From 2012 to 2020, the government launched a series of ICT programmes for the elderly, for enhancing the elderly adoption of ICT and enlarging their social circles. As shown in Table 3.1, it is found that the activities, technologies, and range and volume of participants in the programme have expanded and evolved year by year (Office of Hong Kong Government Chief Information Officer, 2020).

Table 3.1 ICT programmes for the elderly

Year	Contents	Participants
2012-2013	Established supporting projects to enhance elderly access, knowledge, skills and receptiveness on the use of ICT, mainly for computer and mobile phone, with the perceptive of improving their life quality and broadening their social circle.	Around 4000 elderly persons
2013-2014	Outreach programmes for hidden elderly to arouse their awareness and improve their interest of ICT	38 elderly homes, and over 1000 elderly persons
2015-2016	Second round outreach programmes that extended the service scope to cover elderly receiving day care services and home care services	63 residential care homes and day care centers and over 2000 elderly persons
2017-2018	Third round of the programmes that extended to elderly with dementia with the view of helping them through the aid of digital technology	2500 elders, and over 100 residential care homes and day care centers
2018-2020	Two years programme that launched new enriched ICT training programme for elderly to provide advanced training to enhance their capability of digital technology usage in daily life	11 elderly academies

To create a favorable environment for gerontechnology development, the Hong Kong government has established certain measures. In 2018, the government launched a HK$ 1 billion 'Innovation and Technology Fund for Application in Elderly and Rehabilitation Care' to subsidize elderly service organizations to purchase, rent, and trial use of gerontechnology products and services (Hong Kong Social Welfare Department, 2020).

Moreover, the government progressively increases the public expenditure on the elderly. In 2020, the expenditure on the elderly reached HK$ 91.9 billion (20.8% of total public expenditure) with an average growth rate of 11.4% (Hong Kong Research Office of Legislative Council Secretariat, 2019). In addition to financial input, the government dedicates to create opportunities for industry practitioners and professionals to exchange knowledge and share their innovative gerontechnology, such as the 'Gerontech and Innovation Expo cum Summit' since 2017 and 'GeronTech Cluster' launched in 2019 (Hong Kong Productivity Council, 2020). From the legal aspect, the issue of some outdated regulatory systems and policies toward gerontechnology have been posted in the recent legislative assembly and the government promised to improve the current systems through collaboration among all related departments (The Government of Hong Kong, 2017).

3.1.3.2 ICT-oriented PSS

There are numerous examples of research investigating older adults' acceptance of ICT in which the focus has mostly been on older peoples' usage of computers, the Internet, and mobile phones. In fact, however, ICT has a much wider application in gerontechnology. Ivankina et al. (2017) identified four areas of ICT application for older people's daily life, namely, finance, administrative activity, communication and leisure, and methods of technology adoption. Besides these, ICT can also be adopted in other gerontechnology domains, such as healthcare. Bouma et al. (2009) distinguished five domains of gerontechnology: housing and daily living, communication and governance, health and self-esteem, work and leisure, and mobility and transport. By integrating these two classification schemas, this study adopted a three-category classification system for ICT for older adults: communication and leisure, healthcare, and housing and daily living. In each application area, one typical application is demonstrated to elaborate on the progress and future trends of its associated PSS development.

(i) Communication and Leisure

The senior phone is one of the most successful products adopted by older people for communication. Some years ago, many older people preferred to use the mobile phone without smart functions, especially the oldest old, due to the complexity of smartphone operation. At that time, older adults' primary need on the mobile phone was to obtain assistance in emergencies. Nowadays, the landscape has changed, and more and more activities need to be accomplished through the smartphone. In addition to the safety motivation, older people also regard the mobile phone as social interaction and task-organization tool (van Biljon & Renaud, 2008). As a result, some gerontechnology producers are currently developing senior specialized smartphones, which add some basic smart functions to the senior phone. However, this kind of smartphone lacks functionality compared with the normal smartphone.

On the other hand, most normal smartphones do not address the distinctive needs of older users in their original design. As a result, the difficulty for older people in using smartphones has increased. To successfully capture the knowledge of smartphone use, most of them need assistance from others. This situation has raised concern by both government and non-governmental organizations (NGOs), which leading them to publish some trainings and courses to facilitate older adults' use of smartphone, such as the aforementioned 'ICT programmes for the elderly' by the Hong Kong government.

Recognizing these progresses, some smartphone providers, such as Apple Inc. (2021), have launched tutorials to teach their customers how to use their product. To improve usability, some elder-friendly features have been added to the smartphone through the upgrade of software, such as adjustable text size, text-to-speech conversion, audio descriptions, and voice control (van Dyk et al., 2012). Many producers are engaged in the development of customized systems for the elderly that will possibly be launched during the next few years.

(ii) Healthcare

Telecare comprises a mixture of computing, telecommunications, and information technology to support older people's health protection at a distance. It may provide health services to the end-user directly through remote systems. This kind of service has been available in some western countries for more than 20 years, and it has also been applied in Hong Kong for more than 10 years. The first generation of this type of system consisted of a device with wireless remote triggers. When the user pressed the trigger, the system would automatically contact the administrator or help center.

With the development of smart technology, the system has further evolved. Facilitated by the popularization of broadband communications and networks, and the advancement of sensor technology, the current second-generation systems is able to collect the user's life information and monitor and measure the user's body condition by itself. Now, its functions include not only the emergency contact and alert, but also the measurement of physiological functions, medicine reminders, and the detection of unusual situations. The third generation of telecare systems would involve the support of medical personnel and realize the intelligent monitor. In the current outbreak of COVID-19, some advanced telecare systems have commercialized this function and will be diffused further during the next few years. In the foreseeable future, the fourth-generation telecare will integrate audio-visual technology to enable virtual consultation from healthcare personnel, hence reducing the need for doctors' home visits and older people' s hospital visits. In this way, older people would feel more empowered in their life (Kerbler, 2017).

(iii) Housing and Daily Living

Companion robots are designed for the purpose of accompanying and assisting older adults to live active, independent and engaged lives. One type of companion robot associated with ICT is the intelligent speaker for the elderly. Its voice interaction function allows older adults to communicate with the robot and control the system through voice.

Older people may use it to carry out various activities, including daily life management, accessing social media, playing music and video, and health management. From the service perceptive, as intelligent-speaker providers have a sufficient ability to create a smart product, they always integrate the smart feature into their service as well, such as intelligent customer service. The recently developed companion robot, ElliQ, further improved the 'intelligence' of the system. Through machine learning and computer vision, it can provide proactive suggestions to older adults in their daily life. These suggestions are personalized according to the previous experience, records, and preferences from the user, which is considered as individualization of services (ElliQ, 2021). It also allows caregivers to pre-set some goals and the robot can automatically make a decision based on the context. The product is currently in the internal testing phase and will launch to the market soon.

In the next stage, the intelligent speaker might focus on integrating voice technology with other products. Although from the technology aspect, the current product is able to realize the voice control of other home electronic devices through system integration. The present devices in most elderly's home lacks smart functionality to integrate with intelligent speakers. It takes time to achieve a full connection, and when it accomplishes, the convenience of older people at home could be highly improved. Moreover, the voice assistants will continue to offer more customized experiences with more human-like interaction in order to provide a more real feeling to older adults of being accompanied. At that time, many intelligent speaker providers will formulate the smart PSS (Yu et al., 2020).

3.1.3.3 Technology and Research Development

ICT technology is an ever-changing field and those who want to remain at the helm of innovation must be aware of the latest trends. Information network infrastructure is the foundation upon which all other advanced technologies and functions in this domain will be based. The years 2020 to 2021 are the period during which network upgrading from 4G to 5G will take place. The commercialization of 5G will usher users into a new era of improved network experiences. The Chinese government is currently dedicated to constructing information network infrastructure and it believes the 'digital divide' among older adults will be narrowed through the popularization of 5G (Yu & Han, 2020). During the next decade, 6G technology might be launched, which would integrate satellite signals with user systems on the ground.

Along with network technology, big data has also achieved advancement in technology use for the aging. It evolves from basic big data analysis to tracking and analyzing all possible user behaviors, which largely supports the health monitor product. Another widely applied technology is artificial intelligence (AI). Its integration into gerontechnology is expected to be predictive, personalized, preventive, and participatory, which could bring disruption of current care processes and relationships. Virtual reality (VR) will also become prevalent and as mentioned in the previous section, some aspects of the medical profession are projected to rely upon VR for interaction and some treatments with older adults in the coming years. On the other hand, the growing use of these technologies may leave a high amount of personal data at risk of breaches. As a result, the product and service providers need to address cybersecurity and privacy issues and find a practical solution to the envisaged problems.

From the research perspective, many studies of older people's perception of ICT and factors that influence older adults' ICT acceptance has been conducted. Although variations exist across the studies, usability, affordability, accessibility, value, emotion, independence, experience, confidence, technical support, and social support are the factors commonly agreed upon by researchers as being the most salient (The Government of the Hong Kong Administrative Region, 2017). After identifying the older adults' adoption condition (what) and the reasons behind their low ICT acceptance (why), researchers will increasingly focus on the problems associated with 'how' in the next stage. More research on the methods, approaches and applications for the development of ICT and its related PSS will be conducted. At that stage, issues related to the ethical implications of ICT for older people need to be considered, and researchers have a responsibility to facilitate the industry's practical implementation of ethical principles (Macedo, 2017).

3.1.3.4 Challenges

After analyzing the current status and future trends on social change and older adults needs, ICT-oriented PSS evaluation, and ICT technology and research progress, three key challenges have been identified that may be encountered in the process of ICT-oriented PSS development.

(i) Elderly People's Lower Acceptance Level of ICT

Elderly people are considered to be a later adopter of technology, as they always tend to favor the product with which they are familiar and resist new technology. Despite the increased adoption of the Internet, computers, and smartphones, older adults still exhibit a lower level of ICT usage. Lots of factors have been identified that potentially influence older peoples' ICT acceptance, as listed in the previous section. The implementation of PSS can help to moderate some barriers to the adoption of technology by elderly people. For instance, technology support can be accomplished through integrated services provided by the manufacturer, and the affordability problem may also be alleviated as PSS has the ability to reduce the product cost by providing alternative scenarios for the use of product, such as rental and sharing schemes (Mont, 2002). However, how to adopt the PSS and applying which kind of PSS is still a challenge for the ICT providers. If they fail to integrate an appropriate PSS, it might even be counterproductive to acceptance by older adults.

(ii) Lack of Collaboration Among Different Stakeholders

ICT for older adults can be considered as one type of gerontechnology. Given its natural interdisciplinary attribute, there is a necessity for cross-sectoral collaboration from different stakeholders to promote the development of the PSS application in ICT gerontechnology. The report from 'Our Hong Kong Foundation' indicates that Hong Kong is insufficient in collaboration within the gerontechnology ecosystem among different stakeholders, which, as a consequence, obstructs the advancement of ICT products and services (Wong et al., 2017). Each sector and stakeholder have its role and advantage in the research, development, testing, commercialization, and enhancement of ICT-oriented PSS. For instance, the technology produced by business sometimes needs helps from NGO sectors to accomplish some service functions, as they have a tighter relationship with the end-user. Although evidence exists for collaborative efforts in Hong Kong, such as the collaboration between research institute and university, compared with the world-leading regions on gerontechnology, such as America and Japan, the dialogues and partnerships are far from sufficient.

(iii) Outdated Regulatory Systems and Principles

The technologies and their PSS designed for older adults are different from other groups of people, as older people are physically and cognitively different from younger

adults, and more stakeholders are involved in this process. As a result, the current regulatory systems in Hong Kong lack the effectiveness to guide the implementation of ICT-oriented PSS for the elderly. More sophisticated regulatory frameworks and policies for gerontechnology are needed to direct the design, production, configuration, commercialization, and use of ICT-oriented PSS. The regulatory departments should collaborate with relevant stakeholders to provide a solid approach to support the rights of older people, especially focus on the ethical issue generated from the development and use of ICT-oriented PSS. Simultaneously, policies and regulatory frameworks that recognize, promote, encourage, and support the involvement and continuing contribution of elderly people to society is another critical issue that needs to be considered (Camarinha-Matos et al., 2013).

3.1.4 Roadmap

Based on the results of the previous sections, a roadmap of ICT-oriented PSS for older adults developed here is shown in Figure 3.3. In order to assess the likely timescales of ICT evolution, several studies of the technology roadmap for the ICT industry have been consulted. Four sub-periods have been identified, namely: ‘past’, representing PSS and technology viable within the past 5 years (2016-2020); ‘short-term’, representing a window of current 1-2 years (2021-2022; ‘medium’, representing the next 2-5 years (2023-2025); and, ‘long-term’, representing the next 5-10 years or beyond (2025-2030). This roadmap comprehensively demonstrates the progress and trends of ICT-oriented PSS in silver market through mapping out the social needs and drivers, ICT product, service and its functionality, and technology and research advancement.

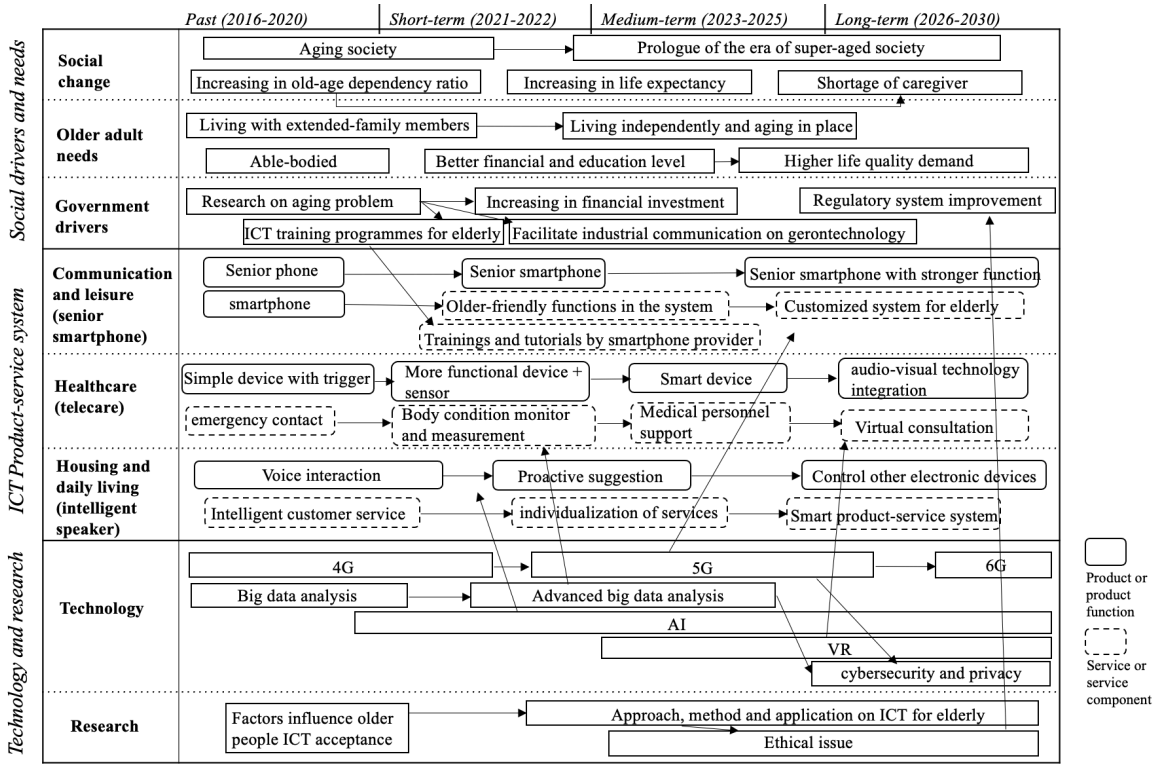

Figure 3.3 The roadmap of ICT-oriented PSS for older adults

3.2 Micro analysis of gerontechnology acceptance by older adults and their satisfaction with its servitization in Hong Kong

After obtaining the knowledge of research and industrial progress on gerontechnology product service systems, this study aimed, from micro perspective, to conduct an empirical study to identify current older adults' opinions and acceptance towards technology and its related services.

The literature review and results of the macro analysis have sufficiently demonstrated older adults' low technology adoption compared with young people, especially the advanced technologies (i.e., more recent, smart, or emerging technologies). Gerontechnology specifically for older adults has been developed to mitigate this situation. Phones for seniors, designed with big buttons, big screens, a long battery life, and hearing aid compatibility, have adequately considered the ergonomics and demands of older adults and gained recognition from them (Conci et al., 2009). Automatic portable medical equipment, such as home blood pressure kits and health and fitness trackers, is another category of products that is highly utilized by older adults. It provides seniors a convenient way to track their health and offers safeguards when they live independently. Whereas, compared with these well-known products, many products were not widely adopted by older adults, some even failed to overcome the 'valley of death' (Islam, 2017). This implies that the existing design practices of products and technologies may attract less attention from senior users in regard to their acceptance as well as adaptation, and accordingly technology innovation may fail in the silver-hair market. Therefore, understanding older adults' needs, perceptions, and behaviors of technology usage is critical for successful gerontechnology design.

This study conducted in-depth micro analysis through an empirical study to ascertain current older adults' technology experience, their view of different acceptance factors, and their perspective on the services for technological products. Although some pioneers have committed to exploring older adults' acceptance and adoption of technology through empirical studies (Arthanat et al., 2020; Lancioni et al., 2017; Chen & Chan, 2014a), the evolving social and technogloical contexts with corresponding changes in the needs, expectations, and values of older adults have resulted in a lack of validity of previous assessments and existing systems. Additionally, several gaps identified in the literature review and the macro analysis have been addressed and filled in this study.

Firstly, to understand older adults' technology acceptance and adoption, its influencing factors have been widely studied, but there is still no consent on the list of variables that affect technology utilization by older adults in a systematic study. This study summarized the factors influencing older adults' technology acceptance and generated a more comprehensive list.

Secondly, it is also found that the supporting services, as a key to facilitate technology usage, is rarely addressed by both gerontechnology researchers and practitioners. According to the need mentioned above, the literature suggests that innovation strategies for the development of products integrated with services and technologies for older people are one of the most significant issues for the stakeholders (An et al., 2021; Chang et al., 2019; Menghi et al., 2018). In fact, in Hong Kong, the government has recognized the difficulty for older people to adopt technology and the importance of supporting services. Hence, the government has launched a series of ICT projects since 2012 to enhance older adults' access, knowledge, and skills with regard to digital devices as mentioned in the macro study (OGCIO Hong Kong, 2022). Nevertheless, government power alone is far from enough to meet older adults' demand for services. The government's role is more related to advocacy and providing supplementary support to assist older adults to learn how to use technology. Manufacturers and companies that have adopted gerontechnology, designers, and engineers should be the main forces providing services to support older adults' technological product usage and thereby improve their technology acceptance. Unfortunately, the service part has been neglected by most of them, and to the best of our knowledge, there is no empirical study that yet investigates the service aspect of gerontechnology. As a result, one aim of this study was to explore the current status of gerontechnology services provided by manufacturers.

Through this process, the present study not only provides an in-depth understanding of current older adults' perception and usage of gerontechnology products and services but also a paradigm for user technology adoption analysis in a more systemic way.

3.2.1 Conceptual framework

To investigate older adults' technology acceptance and gerontechnology servitization progress, this study aims to examine three key issues, which are older adults' gerontechnology knowledge and experience, factors influencing their technology

acceptance, and older adults' views on servitization of gerontechnology. The conceptual framework is presented in Figure 3.4.

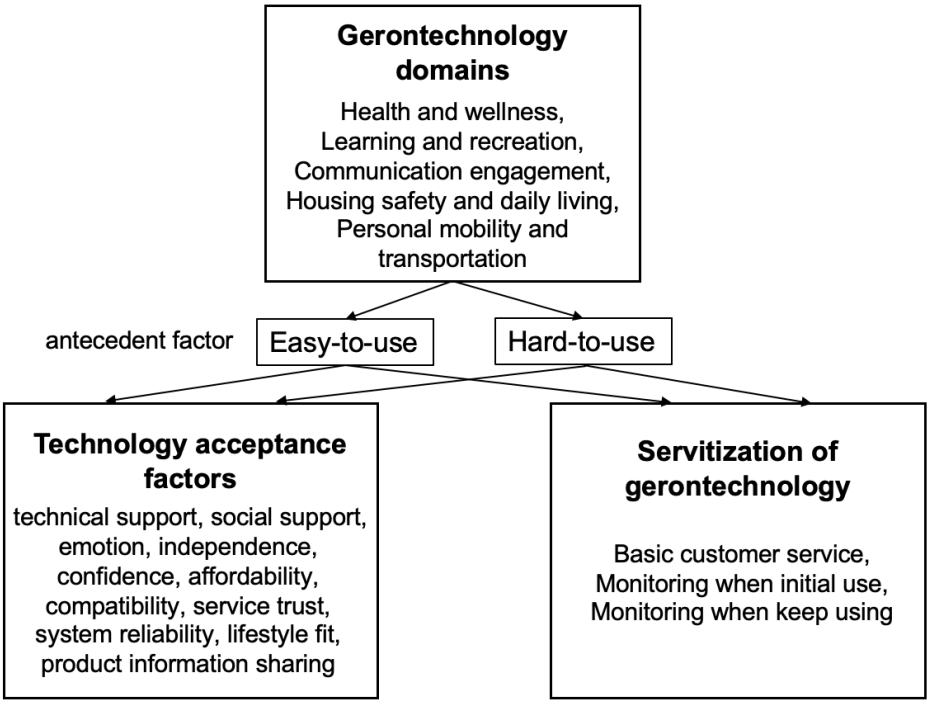

Figure 3.4 Conceptual framework

3.2.1.1 Gerontechnology domains

Older adults' gerontechnology knowledge and experience was assessed by their usage of gerontechnological products in different domains. By comparing and contrasting the classification methods in literature review, it is found that when aspects of technology are addressed, most of the studies tend to classify gerontechnology by goal orientation and the technology application domains can be summarized into five categories, which are health and wellness, learning and recreation, communication engagement, housing safety and daily living, and personal mobility and transportation. This study stands in these five domains to carry out the overall research as shown in Figure 3.5.

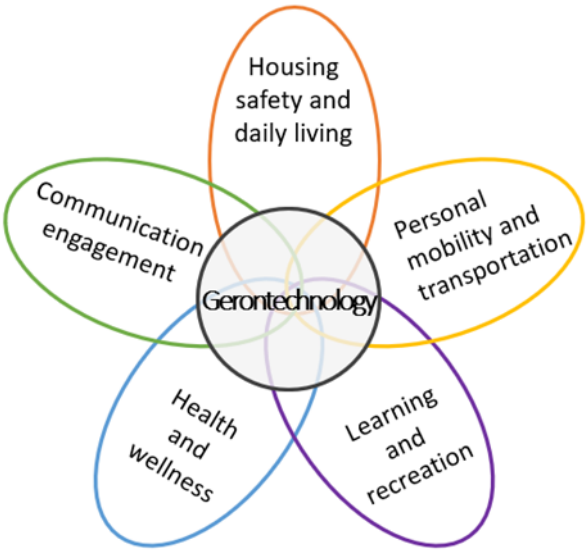

Figure 3.5 Gerontechnology Domains

(i) Health and wellness

Great importance has always been attached to health and wellness by older adults as people's physical and mental capacity changes with age and there is a growing risk of disease when older (Chen et al., 2014). Keeping healthy is the first condition for realizing many ambitions of daily life. As a result, health-related technology has received enormous attention in both academic and business circles. Various technological products have been launched to the market to assist or track the elderly's health condition, such as personal emergency response systems, medication reminders, and wearable healthcare technology (Talukder et al., 2021).

(ii) Communication engagement

For the younger generation, smartphones, computers, the internet, e-mail, and social media are essential companions in their life. With regard to older adults, despite their lower level of adoption of the internet and electronic devices compared with younger people, recent surveys indicate a dramatic increase in older adults' information and communication technology usage. According to the Hong Kong Census and Statistics Department (2020c), the percentage of persons aged over 65 who use the internet increased from 56.3% in 2018 to 62.2% in 2019 and this group of people also accounts for the highest growth rate among all age groups. As a result, communication and engagement technology tends to play a vital role in older adults' social lives.

(iii) Housing safety and daily living

Housing safety and daily living technology is indispensable for realizing the concept of 'aging in place'. The existing gerontechnology in this area contributes to a more comfortable, convenient, safe, and secure living environment for the elderly. For instance, electric cooking products such as microwave ovens make cooking tasks less complex. Technology such as security system monitoring and home alarms could help to ensure the privacy and security of seniors. Additionally, the emerging smart home technology takes user experience of home digital devices and security systems to a new level by connecting them to wireless networks; thus, users can control devices through simple actions.

(iv) Personal mobility and transportation

Mobility and transportation are the keys to independence, freedom, and meaningful engagement for the elderly. It is an active technology domain for not only transportation, such as vehicles, the underground, and trains but also the infrastructure and assistive equipment, such as wheelchair access, Global Positioning System (GPS), and elevators. All of these should be robust and fully considered for aging people.

(v) Learning and recreation

Based on Maslow's hierarchy of needs (Maslow, 1943), after satisfying the basic needs of communication, safety and health, people will have the wish and capacity for psychological and self-fulfil needs. For the elderly, this includes continuous learning, contributing through continued work or even volunteering, and staying aware and active in society.

3.2.1.2 Older adults' technology acceptance factors

Twelve factors were identified to explore the reason behind older adults' technology acceptance behaviour. Through the literature review, recent and popular studies on older adults' technology acceptance and adoption have been summarized. Accordingly, the frequently mentioned factors: independence, emotional enjoyment, social support, technical support, confidence, affordability, compatibility, service trust, system reliability, lifestyle fit, product information sharing, and ease of use, are considered in this study to investigate the reason behind older adults' opinions on technology usage.

Unlike most previous studies that viewed ease of use as on par with other influencing factors, this research regards ease of use as an antecedent to the other determinants. Expanding on this perspective, Lin (2013) posits that usage is theoretically influenced by the perceived ease of use. Importantly, people's attitudes and reactions differ between systems they perceive as easy to use versus those they find difficult to navigate. Davis et al. (1992) further reinforced this notion, suggesting that a technology application perceived to be easier for users to operate is more likely to be accepted. Taking this into consideration, this study attempts to further explore how the perceived ease of use influences older adults' perception of other factors, thereby adding knowledge of product-service design when facing different product complexity. The ease of use in this study was regarded as the antecedent factor to understand the difference in older adults' perceptions in terms of technology with different usage difficulty and explore how different levels of services are needed for older adults when using technological products with different usage difficulties.

3.2.1.3 Servitization of gerontechnology

The three levels of service introduced in literature review, including 1) base service, 2) intermediate service, and 3) advanced service, were applied to assess older adults' views towards current services for gerontechnology products. The central part of servitization is the delivery of product-based services (Baines et al., 2009). A key characteristic of servitization is its strong customer orientation (Ruiz-Alba et al., 2019). Customers are not just provided with a homogeneous product but a wider more tailored 'solution'. For the older population, it should be more adaptable, as they are more multifarious in reliance, ethnicity, well-being, physical condition, and financial status. Apart from this, previous studies have proved that customer service level can affect customer satisfaction. A higher level of customer service quality can lead to positive outcomes (Afthanorhan et al., 2019; Prakash & Mohanty, 2013; Woodside et al., 1989). Researchers assert that while service quality is the primary metric used to evaluate a service offering, consumer loyalty is often viewed as the downstream result of specific service interactions (Lee et al., 2000). In this study, the three levels of service can be represented as 1) basic customer service, 2) monitoring when initially used, and 3) monitoring of continuous usage.

3.2.2 Participants

The samples were collected from five elderly service centres in Hong Kong by convenience sampling. The research object of this study was 'young old', as this group of people score better on the measurement of intelligence and capacity. In other words, younger older adults have stronger demands for an independent life and higher potential and ability to use technological products and services. A widely used segmentation defined older adults aged between 60 and 75 years old as young-old (Lee et al., 2018), while considering that in Hong Kong community support services are provided for those aged above 55. Therefore, people aged 55-75 were invited to take part in this study, and respondents aged 55-59 were recruited for future forecasting purposes. In total, 104 older adults joined this study. The largest age group in this dataset was 65-69 years old (44.2%). In terms of their living condition, 87.50% (91) of participants lived with their relatives, 57.69% (60) of participants lived in public housing and 55.77% (58) of participants rented a property. The gender ratio was about 3:1 (76.9% were females and 23.1% were males). The imbalance of gender may be due to females being more willing to join the activities in elderly centres. Regarding to 'aging in place', most participants satisfied with their living environment, where 81.73% (85) of participants satisfied with their home, 77.88% (81) of participants close to their community and 46.15% (48) of participants often having family and friends visit. The complete demographic profile and their aging in place condition are shown in Table 3.2 and Table 3.3.

Table 3.2 Demographic profile of the participants

	Frequency (N)	Percentage (%)
Age		
55-59	8	7.69
60-64	27	25.96
65-69	46	44.23
70-75	23	22.12
Gender		
Male	24	23.08
Female	80	76.92
Living Condition		
Living Arrangement		
With Relatives	91	87.50
Living Alone	13	12.50
In Nursing Home	0	0
Type of Housing		
Private Housing	35	33.65
Home Ownership Scheme (HOS)	7	6.73
Public Housing	60	57.69
Village Housing	2	1.92
House Holding Status		
Self-Owned	41	39.42
Rented	58	55.77
N/A	3	2.88
Education level		
No school/Pre-primary	7	6.73
Primary	14	13.46
Lower Secondary	35	33.65
Upper Secondary	30	28.85
Matriculation	7	6.73
Bachelor or equivalent and above	11	10.58
Marital status		
Married	83	79.81
Divorced	1	0.96
Separated	4	3.85
Widowed	12	11.54
Unmarried	2	1.92
Living with partner	1	0.96
N/A	1	0.96
Working status		
Full-time work	2	1.92
Part-time work	6	5.77
Retirement	92	88.46
Self-employed	4	3.85
Economic status		
Low level (less than HKD 10,000/month)	77	74.04
Middle level (HKD 10,000/month to 30,000/month)	22	21.15
High level (higher than HKD 30,000/month)	4	3.85
N/A	1	0.96

Table 3.3 Aging in place information

Aging in place	Frequency (N)	Percentage (%)
Satisfaction with home		
Strongly unsatisfied	0	0
Unsatisfied	1	0.96
Natural	15	14.42
Satisfied	64	61.54
Strongly satisfied	21	20.19
N/A	3	2.88
Frequency of leaving community		
Never	2	1.92
Rarely	18	17.31
Occasionally	51	49.04
Usually	32	30.77
N/A	1	0.96
Closeness to community		
Very not close	1	0.96
Not close	2	1.92
Natural	20	19.23
Close	58	55.77
Very close	23	22.12
Visits from family and friends		
Yes	48	46.15
No	55	52.88
N/A	1	0.96

3.2.3 Procedure

Before the survey conduction, this study was reviewed and approved by the Human Subjects Ethics Application Review System (HSEARS) from the Hong Kong Polytechnic University (code: HSEARS20211026010). This study employed a questionnaire survey method. A face-to-face structured interview was used for data collection rather than a self-administered or online questionnaire. There were two reasons for choosing face-to-face interviews: firstly, 60.4% of older persons in Hong Kong have lower than a secondary level of education (Hong Kong Census and Statistics Department, 2016); secondly, this research aimed to identify older adults' technology acceptance. As a result, an online method would lead to a lack of sample representativeness. Before finalizing the questionnaire, it was reviewed by experts in sociology and engineering to assure content validity and a pilot study was conducted to eliminate possible ambiguities and build better reliability. Based on the results from the pilot study, the questionnaire was revised and finalized. Five elderly service centres were involved in the older adults' enrolment and a cover letter introducing the study was sent to their administrators for agreement. The data collection process was conducted after achieving the agreement from the elderly service centres. The elderly service centres provide day care, health promotion, life education, recreational activities etc., to facilitate them to live healthy, positive, active and happy lives when 'aging in place'.

Five interviewers, who have received training to ensure consistent survey results, were employed to present the questions. They received training in standardized question phrasing, response handling, question interpretation, and situational management. Before participating in the study, all participants were required to provide written informed consent (Appendix I and Appendix II), which included audio recording and transcription of the interviews. For participants aged 70 and above, the MoCA test was administered prior to the interview to ensure they possessed the cognitive capacity to provide reliable responses.

During the interview, the participants answered questions based on their knowledge and followed the interviewers' instructions. A brief introduction to the project and a brief explanation of the terminology used was given to the participants to help their comprehension. The interviewers presented the questions orally, following the written questionnaire, and the interviewees responded according to the provided instructions. The interviewers then recorded interviewees' response by filling in the questionnaire. Each interview was held for about 15 to 20 minutes and their answers were assured to be anonymous and confidential and would be used for this research only. Data transcription was carried out by one of the interviewers. To minimize transcription errors, each response was assigned a unique code to streamline the data entry process.

3.2.4 Measurement

Appendix III shows the survey questionnaire. The measurement of this study comprised five parts: 1) demographic information; 2) gerontechnology knowledge and experience; 3) technology acceptance factors; 4) older adults' view of services; and 5) older adults' living conditions.

Gerontechnology knowledge and experience was measured by the degree of technology usage. In total, 22 common technological products in daily life were identified and classified into the five gerontechnology domains (health and wellness, housing safety and daily living, communication engagement, learning and recreation, and personal mobility and transportation). The degree of usage was divided into five levels: 'never heard' (1), 'heard but never used' (2), 'used at least once' (3), 'occasionally used' (4), and 'usually used' (5).

The 12 factors identified above were used to evaluate older adults' technology acceptance factors, including technical assistance, social support, emotional enjoyment,

independence, confidence, affordability, compatibility, service trust, system reliability, lifestyle fit, product knowledge sharing, and ease of use. In this part, the participants were first asked to select the easiest-to-use and hardest-to-use technology among the 22 listed items and then evaluate the factors that influence their perceived ease of use based on the technological products they chose. The factors were measured by a 5-point Likert scale to indicate their agreement of the description for related factors.

Older adults' view of services was also measured according to two dimensions: services for easiest-to-use products and hardest-to-use products. Four supportive services for technology adoption, including instruction book, customer service hotline, tutor at the beginning and tutor during the product usage, were listed and the participants were asked about their need for a service, whether it had been provided, whether it met their expectation and their satisfaction with the current situation. Question types included yes/no questions and 5-point Likert scale questions.

Demographic information (including age, gender, living condition, education level, marital status, and working status) were measured by their categorical survey responses. In addition to basic demographic information, with the purpose of understanding the 'aging in place' phenomenon, this study thoroughly investigated older adults' living condition. In this part, their family status (including whether they live with teenagers, their financial status, source of income) and their relationship with their community (including their satisfaction with their home, their closeness to their community, and the frequency of friends visiting) were measured by using categorical questions.

3.2.5 Results

Data were analyzed by the statistical software Statistical Package for Social Sciences (IBM SPSS v.26). Bayesian statistics were used for inferential statistic and correlation analysis among the different factors.

3.2.5.1 Measurement assessment

Considering that some of the variables proposed in this study have never been examined in previous empirical studies, common method bias can be a potential problem; therefore, as recommended by Podsakoff et al. (2003), Harman's single-factor test was carried out to check the common method variance (CMV) of variables in the three themes. The results of principal axis factoring (PAF) revealed that the total variances extracted by one factor were 26.30%, 19.41%, and 15.41% for gerontechnology experience and

knowledge, technology acceptance factors, and services of gerontechnology, respectively, which indicate that no single factor emerges and accounts for majority of the covariance. Thus, these results suggest that CMV is not a pervasive issue (Chang et al., 2020).

The multicollinearity issue was also considered through the calculation of tolerance values and variance inflation factor (VIF). For all variables in the three themes, including gerontechnology experience and knowledge, technology acceptance factors, and gerontechnology services, the tolerance values were greater than 0.01 and VIFs less than 5, indicating that multicollinearity was not a problem (Hair, 2009).

For the validity and reliability of the scale, Kaiser–Meyer–Olkin measure of sampling adequacy (KMO), Bartlett's Test of Sphericity, and Cronbach's Alpha were performed. The results (Table 3.4) show that KMO were all greater than 0.7 (the recommended minimum value is 0.5) and Bartlett's Test of Sphericity was significant, which indicates that the dataset was adequately sampled (Gravetter et al., 2020). All Cronbach's alpha coefficients were above 0.7, demonstrating good internal consistency (Hair, 2009).

Table 3.4 Validity and reliability of the scale

	KMO	**Bartlett's Test of Sphericity**		**Cronbach's α**
		Chi-Square	Sig.	
Technology experience and knowledge	0.79	827.43	0.00	0.86
Technology acceptance factors				
For easy-to-use	0.72	436.45	0.00	0.77
For hard-to-use	0.76	336.41	0.00	0.76

3.2.5.2 Gerontechnology knowledge and experience

Gerontechnology knowledge and experience were measured by having the participants indicate whether they had heard of or used the listed 22 gerontechnology products. According to the statistical results shown in Table 3.5, the participants had the highest experience of communication engagement technology (3.98) followed by personal mobility and transportation technology (3.20) and housing and daily living technology (2.79), while they did not have sufficient experience of learning and recreation technology (2.61) and health technology (2.21). Participants from the 55-59 age group generally had higher knowledge and experience of communication engagement technology, housing safety and daily living technology and personal mobility and transportation technology, with a lower score for health and wellness technology.

Table 3.5 Usage experience of gerontechnology in different domains

Items	Frequency (N) (percent %)					Mean ± SD	
	1	2	3	4	5	Full age group	55-59 age group
Communication engagement							
Telecommunication apps (n=103)	11 (10.68)	9 (8.74)	13 (12.62)	48 (46.60)	22 (21.36)	3.59±1.22	3.75±0.46
Smartphone (n=104)	0 (0)	2 (1.92)	1 (0.96)	17 (16.35)	84 (80.77)	4.76±0.67	5.00±0.00
Computer (n=103)	0 (0)	15 (14.56)	23 (22.33)	37 (35.92)	28 (27.18)	3.76±1.01	4.00±1.07
Social media (n=103)	4 (3.88)	15 (14.56)	13 (12.62)	35 (33.98)	36 (34.95)	3.82±1.18	4.38±1.41
Sub-total						3.98±1.13	4.28±0.99
Housing safety and daily living							
Electronic cooking (n=104)	1 (0.96)	27 (25.96)	21 (20.19)	34 (32.69)	21 (20.19)	3.45±1.11	3.50±1.51
Smart home control system (n=103)	14 (13.59)	77 (74.76)	10 (9.71)	1 (0.97)	1 (0.97)	2.01±0.60	1.75±0.71
Automated machine (n=103)	8 (7.77)	49 (47.57)	13 (12.62)	21 (20.39)	12 (11.65)	2.81±1.20	4.13±0.64
EPS，PayPal (n=103)	17 (16.50)	48 (46.6)	19 (18.45)	12 (11.65)	7 (6.80)	2.46±1.11	3.00±1.31
Credit cards (n=104)	3 (2.91)	36 (34.95)	19 (18.45)	24 (23.3)	21 (20.39)	3.23±1.21	4.38±0.74
Sub-total						2.79±1.19	3.35±1.37
Personal mobility and transportation							
Smart bus card (Octopus) (n=103)	0 (0)	0 (0)	0 (0)	3 (2.91)	100(97.09)	4.97±0.17	5.00±0.00
GPS (n=103)	15 (14.56)	43 (41.75)	18 (17.48)	21 (20.39)	6 (5.83)	2.61±1.14	2.75±1.49
Mobility aids device (n=103)	8 (7.77)	89 (86.41)	3 (2.91)	2 (1.94)	1 (0.970)	2.02±0.62	2.00±0.54
Sub-total						3.20±1.48	3.25±1.57
Health and wellness							
Personal emergency alert (n=102)	2 (1.96)	91 (89.22)	6 (5.88)	2 (1.96)	1 (0.98)	2.11±0.49	2.00±0.54
Sensory enhancement assistive device (n=103)	14 (13.59)	84 (81.55)	0 (0)	3 (2.91)	2 (1.94)	1.95±0.58	1.38±0.62
Medication reminder (n=102)	22 (21.57)	71 (69.61)	6 (5.88)	2 (1.96)	1(0.98)	1.91±0.66	1.49±0.54
Health/massage/sports equipment （n=104)	5 (4.81)	48 (46.15)	31 (29.81)	15 (14.42)	5(4.81)	2.68±0.95	2.13±1.13
Health tracking device (n=103)	11 (10.68)	64 (62.14)	13 (12.62)	7 (6.80)	8 (7.77)	2.39±1.03	2.13±1.36
Sub-total						2.21±0.83	1.83±0.92
Learning and recreation							
Recreation apps (n=103)	7 (6.80)	39 (37.86)	25 (24.27)	27 (26.21)	5 (4.85)	2.85±1.05	2.63±1.30
Education assistance program (n=103)	9 (8.74)	49 (47.57)	19 (18.45)	19 (18.45)	7 (6.80)	2.67±1.09	2.50±1.07
Tekikin computer (n=103)	81 (78.64)	13 (12.62)	3 (2.91)	3 (2.91)	1 (0.97)	1.39±0.91	1.62±1.41
Digital camera (n=103)	1 (0.97)	40 (38.83)	33 (32.04)	18 (17.48)	11 (10.68)	2.98±1.02	3.50±0.76
CD / MP3 / MP4 / DVD / VCD (n=102)	5 (4.9)	23 (22.55)	44 (43.14)	19 (18.63)	11 (10.87)	3.08±1.02	3.43±0.98
Sub-total						2.61±1.19	2.74±1.28

In terms of individual items, smart bus cards (4.97) and smartphones (4.76) received mean scores of above 4, having been adopted by most of the participants. Sensory enhancement assistive devices (1.95) and medication reminders (1.91) from the health and wellness technology domain and Tekikin computers (1.39) from the learning and recreation technology domain with mean scores of lower than 2, were not used by most of the participants.

The chi-square test was employed to identify the relationship between gerontechnology usage in different domains and the participants' demographics and aging in place characteristics (Table 3.6).

Table 3.6 Chi-square test of gerontechnology usage in different domains by demographics and aging in place characteristics

	Communication engagement (χ^2)	Housing safety and daily living (χ^2)	Personal mobility and transportation (χ^2)	Health and wellness (χ^2)	Learning and recreation (χ^2)
Demographics					
Age	219.520	321.569	91.886	433.315**	353.847
Gender	15.268	20.856	6.368	9.651	20.937
Education levels	130.810**	115.529**	87.863**	86.218	137.03**
Marital status	103.488**	190.853**	46.140**	201.699**	173.824**
Work status	31.409	49.699	15.463	63.026*	59.517
Economic status	94.752	185.539**	45.931	151.731**	148.600
Living status					
Living arrangement	27.774**	40.635**	11.325*	10.277	25.720
Housing type	71.674*	128.087**	39.148**	69.151	153.212**
House holding status	31.347	62.468**	24.999**	63.151**	91.551**
Aging in place					
Satisfaction with their home	59.378**	49.605	10.542	133.821**	56.695
Frequency of leaving their community	57.241*	64.619	40.109**	52.442	44.092
Closeness to their community	79.682**	70.218	22.248	97.961**	82.105
Visits from family and friends	33.555**	21.347	3.701	21.197	15.911

* $p<0.05$
**$p<0.01$

The results indicate that there is no significant age, gender, and work status variance of gerontechnology experience in regard to communication engagement, housing safety and daily living, personal mobility and transportation and learning and recreation, while the participants' gerontechnology experience varied with education level and marital status. The participants who were more educated and married had greater experience in these

gerontechnology domains. For health and wellness technology, the circumstance was not the same, where the participants' experience was different according to their age, marital status, work status, and economic status. Additionally, the results support the idea that older people's technology experience is also associated with their living status. The relationship between 'aging in place' and technology experience is shown in Table 3.6 as well. Significant variances were found for communication engagement, personal mobility and transportation, and health and wellness domains, while there were no significant differences between 'aging in place' characteristics and usage of housing safety and daily living as well as learning and recreation technologies.

3.2.5.3 Technology acceptance factors

The ranking of the top-5 easiest-to-use and hardest-to-use gerontechnology products is presented in Table 3.7. Among the 22 items, smart bus cards were considered the easiest-to-use product by most participants and smartphones were ranked second. For the hardest-to-use products, computers were distinctly considered the hardest-to-use product as perceived by most of the participants.

Based on the selected easy-to-use and hard-to-use products, 11 perceived important factors were used to determine the reason behind the respondents' choices. One-way ANOVA was performed (Table 3.8) to compare the difference between the factors that older adults consider when adopting easy-to-use and hard-to-use technology. The result yielded a statistically significant effect for most factors except technical support, where $p<0.05$.

For the easy-to-use products, factors including social support, emotional enjoyment, independence, confidence, and lifestyle fit received a mean score of above 4 in the full age group, which means that the participants basically agreed that these are the main reasons influencing their adoption of easy-to-use products.

In terms of the hard-to-use products, the participants' agreement of the acceptance factors underwent a general reduction compared with the easy-to-use products, except technical support. Technical support obtained the highest score of 3.91 among all the factors in the full age group, followed by confidence (3.87) and social support (3.73). Affordability, with a mean score of 2.44, was the factor of least concern for the older adults in the full age group when adopting hard-to-use products. For the 55-59 age group, confidence with an average score of 4.14 became the most important factor when adopting

a hard-to-use technological product and system reliability (2.00) was least considered by them.

Table 3.7 Rank of top 5 'easy-to-use' and 'hard-to-use' products

Rank	**Easy to use** Product/service	Frequency (N)	**Hard to use** Product/service	Frequency (N)
1	Smart bus cards	47	Computers	51
2	Smartphones	33	Social media	9
3	Electronic cooking equipment	7	Smartphones	7
4	Social media	7	Digital cameras	5
5	Credit cards	3	GPS	4

Table 3.8 One-way ANOVA test of significant difference between 'easy-to-use' and 'hard-to-use' products in relation to technology acceptance factors

	Complexity (Mean±Std. Deviation)					
	Easy-to-use		**Hard-to-use**		F	p
	Full age group	55-59 age group	Full age group	55-59 age group		
Affordability [a]	3.97±0.59	3.13±1.13	2.44±0.87	2.86±1.22	128.241	0.000**
Technical Support [a]	3.79±0.93	3.17±1.33	3.91±0.81	3.58±1.40	1.043	0.308
Social Support [a]	4.05±0.91	3.00±1.29	3.73±0.92	2.71±1.50	5.834	0.017*
Emotional Enjoyment [a]	4.15±0.62	3.57±1.13	3.58±0.82	2.83±1.33	28.551	0.000**
Independence [a]	4.25±0.59	4.13±0.35	3.66±0.87	3.83±1.33	31.412	0.000**
Confidence [a]	4.29±0.59	4.00±0.54	3.87±0.96	4.14±0.90	13.817	0.000**
System Reliability [a]	3.96±0.79	4.14±0.38	3.23±1.03	2.00±.071	31.187	0.000**
Service Trust [a]	3.81±0.90	3.75±0.89	3.24±0.98	3.00±1.27	17.872	0.000**
Compatibility [a]	3.78±0.89	3.00±1.00	3.06±1.03	2.60±1.14	25.996	0.000**
Lifestyle Fit [a]	4.20±0.57	4.00±0.00	3.52±0.94	3.17±0.75	36.897	0.000**
Product Information Sharing [a]	3.82±0.89	3.29±0.95	3.34±0.90	3.17±0.98	13.431	0.000**

* $p<0.05$ ** $p<0.01$

[a] Measurement scale from 1 to 5, where 1 represents strongly disagree and 5 represents strongly agree

3.2.5.4 View of service

The participants' opinions of gerontechnology services in terms of easy-to-use and hard-to-use technological products are presented in Table 3.9. From the results, the differences in general opinions of the services, need for the services and service satisfaction are statistically significant between easy-to-use and hard-to-use products. Generally, the

participants held a neutral attitude to instructional services provided by manufacturers so even if the services are excessive when the products are easy to use, and when the products are hard to use, they would have a higher need for instructional services.

Table 3.9 One-way ANOVA test of significant difference between 'easy-to-use' and 'hard-to-use' products in relation to view of services

	Complexity (Mean±Std. Deviation)				F	p
	Easy-to-use		Hard-to-use			
	Full age group	55-59 age group	Full age group	55-59 age group		
General opinion of the services						
No need for instructional services [a]	2.99±1.14	2.63±1.51	2.12±1.05	2.43±1.27	31.14	0.000**
Feel uncomfortable with excessive services [a]	2.99±1.02	3.00±0.76	2.41±1.01	3.00±0.82	15.723	0.000**
Instruction book						
Need for the services [a]	3.12±1.11	3.13±1.36	3.91±0.77	3.43±1.13	33.58	0.000**
Service existence [b]	1.48±0.50	1.50±0.54	1.68±0.47	1.43±0.54	8.382	0.004**
Meet expectations [a]	3.58±0.81	3.00±0.82	3.41±0.88	3.00±0.82	1.099	0.297
Service satisfaction [a]	3.58±0.76	3.50±0.76	2.94±1.10	2.57±1.13	23.46	0.000**
Customer service hotline						
Need for the services [a]	3.06±1.09	3.38±1.41	3.76±0.86	3.86±0.90	24.378	0.000**
Service existence [b]	1.37±0.48	1.75±0.46	1.48±0.50	1.57±0.54	2.435	0.12
Meet expectations [a]	3.08±0.95	2.50±0.71	2.74±0.97	3.00±0.00	2.538	0.115
Service satisfaction [a]	3.26±0.90	2.88±1.25	2.56±0.89	2.71±0.95	30.198	0.000**
Tutor at the beginning						
Need for the services [a]	3.77±0.96	3.88±1.36	4.24±0.60	4.00±0.82	17.114	0.000**
Service existence [b]	1.63±0.48	1.88±0.35	1.61±0.49	1.43±0.54	0.068	0.795
Meet expectations [a]	3.94±0.64	4.00±0.00	3.72±0.93	3.50±0.58	2.151	0.145
Service satisfaction [a]	3.67±0.89	3.00±1.95	3.09±1.25	2.71±0.95	14.496	0.000**
Tutor during product use						
Need for the services [a]	2.69±1.06	3.50±1.20	3.78±0.82	3.57±0.79	64.239	0.000**
Service existence [b]	1.17±0.38	1.75±0.46	1.17±0.38	1.71±0.49	0.002	0.96
Meet expectations [a]	3.28±0.74	4.00±0.00	3.05±1.07	3.50±0.71	0.753	0.39
Service satisfaction [a]	3.41±0.87	3.25±1.28	2.52±0.80	2.86±0.69	55.244	0.000**

* $p<0.05$ ** $p<0.01$
[a] Measurement scale from 1 to 5, where 1 represents strongly disagree and 5 represents strongly agree
[b] Measurement contains two types, 1 and 2, where 1 represents No and 2 represents Yes

For the different types of services, older people are fairly accepting of the current service conditions for easy-to-use products, for which the mean scores of their satisfaction with services at different levels were all higher than 3. As regards the hard-to-use products, their satisfaction on services has an overall decline. All scores were just meet or below 3, representing a neutral or unsatisfaction of the current services. Particularly, requiring a

tutor during product use received the lowest service satisfaction score of 2.52 and the mean score of service existence was only 1.17, indicating that few participants received this service. Most of the participants expressed their need for different levels of services, including instruction books, hotlines, and tutors for early-stage and during product use. Among these services, the participants had the highest demand for tutors at the early stage of product use, with a score of 4.24.

3.2.6 Discussion

Taking the results of gerontechnology experience, technology acceptance factors, and older adults' view of services as a whole, it clearly mapped older adults' gerontechnology acceptance and usage in Hong Kong and revealed the cues of gerontechnology servitization design rationale for manufacturers to consider.

3.2.6.1 Older adults' gerontechnology usage

Earlier studies on older adult technology acceptance and usage have consistently found that the elderly always have a negative attitude towards technology and are less likely to use it (Czaja et al., 2006; Lai et al., 2010). Some researchers in their recent research found that older adults tend to be increasingly active in technology usage and their technology adoption rate is growing rapidly (Lian & Yen, 2014). The results in the present study support this argument. For most of the participants, there are at least four or five technologies that they are familiar with and frequently use in their daily life. This result is also consistent with Chen and Chan's (2014a, 2014b) studies about Hong Kong older adults' technology acceptance. As their study and the present study share the same source of sample (i.e., elderly service centres in Hong Kong) in different timeframes, it increased the comparability of the two studies. Compared with older adults' gerontechnology usage condition in 2014, their technology knowledge and experience have undergone an overall improvement, especially in relation to communication engagement technology. For instance, the usage rate of smartphones in their study was 85.0% and the current study shows that 98.1% of older adults have used smartphones. In terms of computers, older adults' usage of this product has improved from 38.4% in 2014 to 85.4% currently. Generally, older adults have richer experience of communication engagement technology, and technology for daily living, which is in line with Chen and Chan's (2014a, 2014b) findings and studies conducted in other regions (Mitzner et al., 2010).

However, compared with other gerontechnology domains, health and wellness technology receive a lower level of adoption by older adults and their adoption rate has undergone no significant increase compared to Chen and Chan's (2014a, 2014b) findings. This might be because in addition to basic health technology, such as health/massage/sports equipment, this study also involved some newly and advanced health and wellness technologies, such as sensory enhancement assistive devices, medication reminders, and health tracking devices. Most of the participants indicated that they had heard of them but never used them. According to Lee et al. (2011), older adults are always resistant to using computer-based devices or advanced technology. There are two possible reasons to explain this phenomenon: firstly, older adults' decline of physical and cognitive abilities is likely to influence an older person's usage capability of technology. Secondly, different from young people, many older adults lack education and experience in advanced technology, which causes them to be less competent in regard to using the technology (Guo et al., 2013). As a result, even if older adults acknowledge the benefits of advanced health technology, it is difficult to supplant the traditional way unless they perceive both the benefit and necessity of the technology. In terms of the 55–59-year-old age group, although they had a higher technology capability, their need for health technology is relatively low compared with older people; therefore, their experience with technology in the health and wellness domain was even lower than that of the full age group. However, given the higher technology competence, this age group is supposed to have a higher adoption rate of advanced health technologies when they get older.

When looking at the relationship between demographic variables and gerontechnology usage, it is not surprising that older people with higher levels of education are more likely to use gerontechnology, which is consistent with other studies of older adults' technology use (Chen & Chan, 2014a; Werner et al., 2011). Their usage of gerontechnology is also related to marital status, where the participants who were non-widowed were more likely to have a higher level of gerontechnology experience. In terms of age, this study found that apart from the health and wellness domain, the relationship between gerontechnology usage and age is not significant. For health and wellness technology, participants of an older age were even more likely to have greater gerontechnology experience. This result contradicts the majority of studies, but there are some studies that found nonsignificant correlations or positive correlations between age and technology acceptance (Jimoh et al., 2012; Zhang et al., 2013). Through a meta-analysis, Hauk et al. (2018) contend that an overall negative effect has been found between age and technology acceptance, but the

effect is not large, and the age effect is only evident when technologies do not address their prevailing needs. In this study, due to the target group being 'young old', the effect of age became less significant. Regarding health and wellness technology, older adults' usage is probably not related to chronological age, but their physical and health condition is highly correlated.

This study also found a relationship between older adults' technology usage and 'aging in place' characteristics in some gerontechnology domains. Communication engagement technologies have the highest linkage with 'aging in place', regarding which the participants who were more satisfied with their home, more frequently leave their community, are closer to their community and always have friends visiting were more likely to have a greater technology experience. Health and wellness technology usage were found to be closely related to their satisfaction with their home and closeness to their community. In the personal mobility and transportation domain, it is not surprising that older adults who more frequently leave their community have a higher technology usage. Peek et al. (2016) in their study highlighted the impact of two 'aging in place' factors: social network and physical environment, on older people's attitudes towards and usage of technology. They argued that how well the technology matches with their living environment influences older adults' technology use. This may explain why participants with higher satisfaction with their home demonstrated higher adoption of health and wellness technology and communication engagement technology. Their social network is another important factor that positively influences their acceptance of technology, by providing support and advice to them. This is in line with the results of present study that older adults who are more active in 'aging in place' might be more willing or more likely to use technologies related to social interaction.

3.2.6.2 Factors influencing older adults' perceived ease of use

When linking older adults' gerontechnology experience with products' perceived ease of use, the relationship between them is quite interesting. The ranking for easy-to-use products broadly matched the participants' technology experience, but not all the technologies that older adults with rich knowledge and experience use are products they perceive to be easy to use. For instance, computers with a relatively high usage experience were regarded as the hardest-to-use product by most of the participants. This result reveals

that perceived ease of use is not the prerequisite for older adults' technology adoption but when older adults perceive technology to be easy to use, they are more likely to use it more.

Looking one step further, among the top 5 easiest-to-use products (smart bus cards, smartphones, electronic cooking equipment, social media, and credit cards), smart bus cards became the easiest-to-use product perceived by most of the participants. Participants who considered the smart bus card as the easiest-to-use technology believe independence, confidence, and lifestyle fit are the key factors. According to the Hong Kong smart bus card company, Octopus cards limited (2022), more than 30 million cards are in circulation, with an over 98% possession rate among Hong Kong people, which indicates these technologies have penetrated into their daily life. Though surprising, the participants presented sharply divergent views on smartphones and social media. A substantial portion of the participants regarded smartphones as the easiest product to operate (ranked as the 2nd easiest-to-use technology), while there were also some participants who believed that smartphones are hard to use. A similar situation occurred with the social media, which was ranked as the 4th easiest-to-use and 2nd hardest-to-use product among 22 listed technologies. In fact, both smartphones and social media have a relatively complex system with multifunction. More and more activities can be accomplished through these two technologies such as communication, information searching, online entertainment, and online shopping. As a result, smartphones and social media have become widespread in society and become the most commonly used technologies in people's everyday life. The high adoption rate leads to sounder social support, which was considered as a key factor by the participants to determine smartphones and social media as easy-to-use products. The results indicate that the actual complexity of technology is not interchangeable with older adults' perceived ease of use. When external support is sufficient, it may improve users' perceived ease of use.

Contrasting older adults' perceptions of a technology as either 'easy' or 'hard' to use reveals that the underlying influencing factors are not the same, lending support to Lin's (2013) perspective. Regardless of a system's perceived ease of use, factors such as confidence, social support, emotional enjoyment, and independence emerge as highly valued considerations for older adults when contemplating the technology adoption. Expanding on the importance of confidence, Lee and Coughlin (2015) define it in this context as 'freedom from intimidation and anxiety.' They argue that a lack of confidence may diminish older users' satisfaction, perceived benefits, and the likelihood of sustained technology usage over time. Some researchers highlighted the importance of confidence

when older adults use technology. Some other researchers used the term 'anxiety' or 'self-efficacy' (Chen & Chan, 2014a, 2014b; Heerink et al., 2010; Talukder et al., 2020; Vaziri et al., 2020), while they were trying to describe a similar phenomenon. A number of studies found that older users always declared themselves own too little knowledge or too old, which caused them to feel less competent and less in control when using technology (Chen and Chan, 2014a, 2014b; Guo et al., 2013). As a result, confidence became a key factor regarded by many researchers, and our findings corroborated this view. Social support is another factor that was given great weight by the participants. Social support and engagement have been recognized by many studies as critical factors that influence motivation and behavioral intention of technology usage (Ma et al., 2021; Lee and Coughlin, 2015). Wang et al. (2011) defined the people in older adults' social networks, such as their family, friends, and community, as 'technology champions', which can play as advocates, promoters, and helpers, reinforcing their adoption behavior. Ma et al. (2021) further reported that social supports have a substantial effect at the earlier stages of adoption. They foster better emotional and instrumental assistance for technology usage. In other words, social supports help to overcome barriers to adoption (Lee and Coughlin, 2015). Consistent with prior studies stating that enjoyment is a critical intrinsic motivation added to the extrinsic motivation for technology adoption (Talukder et al., 2020; Lee et al., 2015; Heerink et al., 2010), this study confirmed that older users give more consideration to emotional enjoyment. Lee and Coughlin (2015) contended that due to the decline in physical ability, older people may be constrained by social activities and interactions, thus, emotional contact and social connectivity are highly regarded by them. Compared with other factors, independence has been less considered by prior studies as a key factor that affects older adults' technology usage intention. Some researchers explained that this misrepresentation of needs and features is mainly because of stereotypes and social biases (Lee & Coughlin, 2015; Turner & Turner, 2011). The current phenomenon of 'aging in place' expresses their wish for an independent life. The results confirmed the significance of independence in convincing older people that technology, which aligned with Lee and Coughlin (2015) that older adults are more likely to adopt technology that they can use independently or that helps them remain independent.

For an easy-to-use product, besides the aforementioned factors, older adults also pay great attention to lifestyle fit. Some technology acceptance studies regarded lifestyle fit as a key influential factor of usage intention, while many of them have specifically focused on 'technical fit'. Notably, Li et al. (2019) highlighted the significance of user lifestyle

compatibility, particularly for older adult populations. Building on this perspective, Broady et al. (2010) argued that older people may not inherently resist technology, but rather are selective in adopting innovations they deem both beneficial and necessary to their daily lives. Although lifestyle fit might not be a critical factor for young people, the results demonstrated its importance in prompting the adoption of technology for older adults.

On the other hand, for a hard-to-use product, lack of support from outside appears to be the main reason why they believe the product to be hard to use. This result is consistent with previous studies, which found that external support is necessary for older adults to overcome barriers to adopting technology (Lee & Coughlin, 2015; Pang et al., 2021; Wang et al., 2011). In some studies, this support is regarded as facilitating conditions (Chen & Chan, 2014a, 2014b). Considering older adults tend to have lower familiarity with and experience with technology, they always have a stronger demand for external support. Lack of support can turn the adoption process into a challenge. Pang et al. (2021) further argue that technical support is particularly important when older adults adopt new technology. Furthermore, because of the potential differences in the senior population, Lee and Coughlin (2015) suggested that technical support, such as training and manuals, be tailored to older adults.

3.2.6.3 Services for gerontechnology

Some previous studies found that older adults always encounter barriers during the adoption process, which is one of the leading factors behind their low technology adoption rate (Cajita et al., 2018; Peek et al., 2014; Barnard et al., 2013). Therefore, to facilitate technology usage, removing their adoption barriers is an effective way, and services can play a critical role in deflecting obstacles during their technology adoption. As previously stated, physical and psychological differences between older adults and other population groups should be taken into account when designing services and supports for them. The results of this study evidenced the insufficiency of existing services, especially for hard-to-use products. Although participants admitted that most manufacturers offered some necessary guidance and training after a product's sale, such as instruction books, it is far from meeting their requirements. This finding confirmed the concern from Lee and Coughlin (2015) that the service side and experiences of technology for older adults have been overlooked.

Among difference services, this study indicates that older adults have the strongest demand for in-person tutorial or training services. This is in line with several studies that highlighted the need for adequate training and assistance for procurement, installation, operation, and maintenance for older customers (Cajita et al., 2018; Lee and Coughlin, 2015). Despite the appeal from researchers, the results indicate that these kinds of services still lack practice, which leads to the problems that older adults encounter when learning to use technology not being effectively solved or even being put on hold. Some researchers found that accessibility and availability to technical support resources is one key problem caused the unsatisfactory from older adults (Mitzner et al., 2019; Preusse et al., 2017). Their technology learning is more like a process that people engage in during enquiry-based learning (Deignan, 2009). Before they start to adopt technology, it might not be easy to identify the problems. Only when older adults are in the using stage, will the issues and questions be raised, and the knowledge obtained during this time is perceived as easier to absorb and more relevant to their needs.

Based on the results, it is recommended that manufacturers treat products and services as a whole when designing gerontechnology for older adults, instead of regarding a product and its related services as two parts of a system. In other words, at the time of product development, manufacturers should think about how to integrate the service into it to assist older adults to adopt technology, so that when buying a product, older adults can get a total solution from gerontechnology. It was reported that letting users know how to access existing services and quickly respond can have a positive impact on older adults' attitude toward technology (Mitzner, et al., 2019; Lee and Coughlin, 2015). Additionally, it is better for tutorial services to cover a long duration, which allows older adults to use gerontechnology without worries.

3.3 Summary

This chapter attempts to understand current older adults' technology usage situation and their perception of the services provided by gerontechnology manufacturers from both macro and micro perspectives in order to complement the shortage of research on gerontechnology servitization and provide a paradigm for understanding older adults' perception and usage of gerontechnology products and services. The macro and micro analysis together shaped a holistic view of the technology products and services development for older adults.

These two levels of analysis provide contextual framework and specific insights respectively. The macro analysis, through document analysis, provides a broad overview of the gerontechnology landscape, including recent progress, underlying technologies, ongoing research, and social factors driving the field. This creates a contextual framework that highlights key trends, challenges, and opportunities in gerontechnology. The micro analysis through an empirical study on older adults' technology usage offers specific insights into how older adults perceive and interact with technology. This micro-level analysis delves into individual experiences, preferences, and barriers, providing a detailed understanding of user behavior and needs. In this way, the macro analysis offers a bird's-eye view of the field, while the micro analysis provides a ground-level perspective. Together, they offer a comprehensive picture that can drive more informed and effective decision-making.

From a theoretical aspect, a roadmap of technological products and services development for older adults has been formulated in macro study. Instead of the traditional method, such as systemic review, that mainly focused on aggregating existing evidence, it synthesized not only existing research and industry progress but also identified the future trends of product and service for older adults with dynamic linkages of changing environment and technological resources. In micro study, it combines widely used gerontechnology classification methods (Bouma et al., 2007, 2009; van Bronswijk, Bouma, and Fozard, 2003; Laurie, 2019) and develops a more systemic framework of gerontechnology domains. By comparing and contrasting various studies on older adults' technology acceptance factors, 12 highly cited factors have been identified. Differentiated from previous studies, this study treated the 'ease of use' dimension as an antecedent of other factors rather than regarding all factors at the same level.

Empirically, through a quantitative face-to-face interview-based survey questionnaire, older adults' technology experience and knowledge, technology adoption factors and view of services have been investigated. Considering gerontechnology's connection to aging in place, this study explored the relationship between older adults' living condition and their attitude to and adoption of technology. Moreover, it proved the practical significance of regarding 'easy' or 'hard' to use as a precondition, as older adults' views of technology acceptance factors and their need for and expectations of services are distinct. The results show an insufficiency of services provided by current gerontechnology manufacturers,

especially for ‘hard-to-use’ products and the provision of tutor services at the early stage which are most preferred by older customers.

3.3.1 Implications

Several relevant implications emerge from this study. Theoretically, it provides a novel review method to understand the research field. The roadmapping method surpasses traditional review method by offering comprehensive and structured overview of the field, obtaining an understanding of not only the past and current development, but also the future trends of the research area with dynamic linkages of changing environment and resources.

Secondly, this study adds to existing knowledge of gerontechnology by proposing a more comprehensive classification method. Drawing on two widely used classification approaches, it considered both life domains in older adults’ actual daily life and characteristics of aging in place, and segmented gerontechnology domains with a clearer division of their functions. This can be filled by technologically bound products, services as well as the related infrastructure, which may help to sort, summarize, and compare gerontechnology in different domains and achieve a better understanding of technology options in regard to older adults’ quality of life.

Secondly, this study is one of the first investigating servitization progress in gerontechnology, which fills the gap in both the gerontechnology field and servitization discipline. Supported by empirical results, it examined the shortage of current services provided to older adults when adopting technology. Coleman (1998, p.74) stated that ‘Technology should serve people, and the needs of older people will best be served by regarding them as consumers and including them in the research and development process’. As a result, in order to improve older adults’ technology acceptance and adoption, services should be granted a higher level of importance in future studies. This study took a preliminary step in servitization research by understanding older adults’ perception of the present situation, but how to integrate older adults into service design for technology can be further explored in future work.

Thirdly, some researchers argued that prior research fails to reach a consensus on the variables that influence technology acceptance among older adults although they revealed an overlap (Macedo, 2017; Chen and Chan, 2014). This study summarized the factors that are frequently regarded as determinants of older adults' technology acceptance and

generated a more comprehensive list. It may help researchers when structuring models and frameworks for technology acceptance by older adults.

Additionally, although ‘perceived ease of use’ has been widely recognized as a key factor influencing older adults' technology acceptance, this study breaks new ground by exploring the effects of perceived ease of use on other underlying technology acceptance determinants. Researchers such as Lin (2013) and Davis, Bagozzi, and Warshaw (1989) had previously theorized that users' demands, and attitudes can vary considerably based on the complexity of a technology's usage. This study confirms and builds upon that assumption, revealing distinct differences in how older adults perceive and respond to "easy-to-use" versus "hard-to-use" products. These findings deepen our understanding of how perceived ease of use shapes older users' cognitions, attitudes, and behaviors toward adopting technologies.

Practically, the roadmap developed from the macro analysis can guide policymakers, researchers, and industry stakeholders in prioritizing areas for development and investment in gerontechnology. The micro study indicates that most manufacturers mainly focus on product features while ignoring the added value from services and highlighted the insufficiencies in services at this stage. The findings from the micro analysis can inform the design and implementation of technology solutions that are user-centered, ensuring that they meet the actual needs and preferences of older adults. This can lead to more effective and widely adopted technologies.

3.3.2 Limitations and future work

Despite the contributions, some limitations of this study should be acknowledged. Firstly, the document analysis is adopted to formulate the roadmap, which provide valuable insights into complex, emerging fields like gerontechnology. While systematic reviews and meta-analyses offer greater rigor in aggregating quantitative evidence, therefore, the future research would consider integrating both approaches to leverage their respective strengths.

Secondly, it is worthy to note that there is demographic limitation in micro study. Although the sample was randomly selected, all the respondents involved in this study who took part in the activities were from elderly service centres, indicating that they might be more socially active than those who do not go to elderly service centres. Furthermore, the results show a great gender imbalance, where the ratio between females and males is 10:3.

This gender imbalance issue of research sampling also happens in other research fields, such as nursing research (Polit & Beck, 2013), paediatric palliative care (Macdonald et al., 2010), and undergraduate student research (Dickinson et al., 2012). One possible explanation for this situation is that females are more willing to participate in this kind of activity and more willing to share their personal feelings and experience with others, especially strangers (Macdonald et al., 2010; Polit, and Beck, 2013). Nevertheless, some researchers found that gender-derived differences in regard to technology acceptance can be considered slight among older adults (Lian & Yen, 2014; Ramón-Jerónimo et al., 2013).

Thirdly, the effect of branding on perceived usefulness and ease of use could be a limitation in the micro study. A strong brand creates positive expectations, reduces perceived effort, and increases trust, ultimately driving adoption and satisfaction—and vice versa. This study did not specify the brands of the technological products examined; products with different brand strengths may influence how users perceive them.

For future work, in this study, we aim to have a better understanding of current older adults' perception and usage of gerontechnology products and services. Based on the findings in this study, a measurement model can be developed in further study to investigate the relationship among older adults' gerontechnology ability, gerontechnology adoption factor, and their needs for gerontechnology services. It can help to predict older adults' technology adoption behavior and needs and provide guidelines in gerontechnology product and service design.

Subsequently, in addition to the twelve older adults' technology adoption factors identified in this study that based on recent highly cited literature, several other factors frequently mentioned in prior research should be considered, such as perceived risk and quality. Future studies could examine how these factors influence older adults' technology acceptance to assess their impact, thereby refining and updating the current framework.

Older adults' opinion of services was investigated in a relatively general way in this study. Therefore, a further study can be conducted that focuses on service design for technological products, as the quality of services, such as manuals, the service person, and training materials are important factors in older adults' technology adoption. If they have positive service experiences, they may also have a positive attitude towards this product and even find it is easier to engage with a new technology, product, or system.

Chapter 4 Development of gamification approach for enhancing older adults' technology adoption and knowledge transfer

4.1 Introduction

After the research presented in Chapter 3, the researcher obtained a better understanding of gerontechnology development progress and future trends, older people's technology usage, the factors that influence their technology acceptance, and their perception of service. As a result, the questions related to 'what' and 'why' older adults are always associated with lower technology acceptance have been comprehended. The following chapter aims to deal with 'how' to facilitate older adults' technology inclusion.

Based on the findings in Chapter 3, driven by accelerated developments in technology and research, gerontechnology is continually being advanced, such as incorporation with AI and big data. However, the results in the micro analysis indicate that the adoption of advanced gerontechnology by older adults is not expected to be favorable. Despite the increased adoption of the technologies among older adults, such as the internet, computers, and smartphones, they still exhibit a lower level of technology usage. In fact, many studies document that older adults suffer from a reduced interest in accepting emerging technology, and sometimes they are even psychologically resistant to adopting advanced digital technology (Seidler, 2007). Lack of external support (technical support and social support) and confidence have been identified in the micro analysis as the most influential barriers to older adults' technology adoption. As a result, bridging these barriers may offer a disruptive way to increase the technology adoption among older people.

Service is the carrier of support offered by technology providers. As mentioned in Chapter 3, the servitization concept has been widely applied in the gerontechnology field recently, with the aim to facilitate older people's acceptance of their products. Most of them still stem from the product-oriented way of delivering their offers. As a result, gerontechnology has not undergone a significant improvement in adoption among older people. Stronger motivation and more elaborate methods are needed to encourage the technology adoption and knowledge transfer process among older adults, where

gamification, with its feature of motivating and engaging people, is a promising tool.

Gamification of services was defined by Huotari and Hamari (2012) as "a process of enhancing a service with affordances for gameful experiences in order to support user's overall value creation." It has become one of the most popular forms of servitization in recent years and has been increasingly harnessed as a means of motivating people in varied domains, such as industries, education, management, and marketing. It can be seen that most gamification research and practice have focused on the young generation since they are supposed to be more experienced with games and have higher self-efficacy with digital technology; therefore, game features are potentially more appealing to them. Prior research indicates that older adults also play and enjoy games (De Schutter, 2011; Sood et al., 2019; Sun et al., 2017). As a result, there is a great potential to encourage older people's technology adoption through gamification. Unfortunately, studies on gamification applications in relation to older adults are limited and most of them focus on physical health and cognitive psychology areas. In terms of the effectiveness of gamification, despite the benefits of gameful intervention for older adults (i.e., to keep them physically, cognitively, and socially active) having been warranted (Koivisto & Malik, 2021), existing studies still showed mixed results.

Gamification design for older adults should be differentiated from that for the young generation, as they are diverse in many aspects, such as their physical and mental ability, life experience, source of fun, ability with games, preference for game characters, as well as attitude on the activities to be gamified (Altmeyer et al., 2018; Gerling et al., 2011, 2012). Gamification implementation is a highly contextual process, and the usage context and the characteristics of users may affect the gamification outcome to a large extent. A successful case for young adults may not suit older adults. Nevertheless, current gamification design frameworks, models, or methodologies are basically aimed at young people, or their default target users are young people. Generalizing these results to older adults' intervention is challenging and may lead to a poor design. As a result, methodological studies with consideration of senior audiences are needed to improve the gamification effectiveness for older adults as well as extend the research scope with user profiles of gamification.

Addressed at the existing research gaps and opportunities, this chapter aims to develop a gamification design approach for older adults' technology adoption and knowledge transfer. To tailor gamification for older adults, we specifically incorporate design centered on older adults into gamified systems. Following the proposed framework, an experimental

study of mobile payment has been conducted with a detailed description of the gamification approach development.

4.2 Theoretical foundation

4.2.1 MDA framework

Through the literature review, we obtained a basic understanding of the Mechanics, Dynamics, and Aesthetics (MDA) framework. This section elaborates how to use this methodology to understand and design games. It is one of the most fundamental models in game design concerning bridging the gap between game design and development, technical game research, and game criticism. As aforementioned, MDA stands for Mechanics, Dynamics, and Aesthetics, and is related to three components of games: rules, systems, and fun, respectively, as shown in Figure 4.1. As a result, mechanics are considered as the cornerstone of the game, and dynamics and aesthetics can help clarify the relationship between the abstract layers and emotional responses that players may generate (Junior & Silva, 2021).

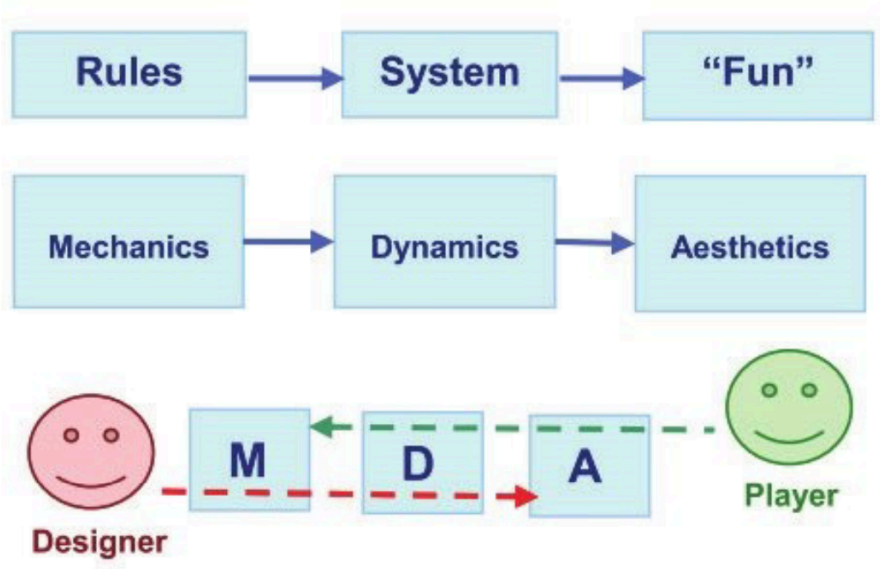

Figure 4.1 MDA framework's order of influence

When designing a game, the first step is to define the core aesthetic or the main experience that the game will evoke in the players. The main aesthetic comes from the designer, and in some cases, it is predetermined by the stakeholders or the purpose of the game. To support the aesthetics, dynamics should be proposed to achieve the aesthetic goals. For instance, challenges can be created by time pressure or opponent play. The

mechanics support the overall gameplay dynamics. By adjusting the fundamental rules of play, we may be able to maintain the competitiveness and interest of lagging players for a longer time, thus achieving the overall dynamics.

Moreover, game mechanics is different from game design elements. According to the definition of gamification, that 'it is the use of game design elements in non-game context,' game design elements are the basic building blocks for gamified applications. They cover a broader scope than game mechanics. Through the literature study, it yielded no single accepted list of default gamification elements. Simple lists are unable to adequately differentiate the various levels of abstraction on which different game elements function (Kim, 2015). Table 4.1 lists the most often encountered gamification elements in the literature, categorized based on the MDA framework (van Elderen & van der Stappen, 2019). These game mechanics and dynamics have been widely integrated into marketing and services to enhance advertising, communication, customer loyalty, and customer engagement (Huotari & Hamari, 2012).

Table 4.1 Most encountered gamification elements in the literature

Mechanics	**Dynamics**	**Aesthetics/Emotions**
Points	Increasing Task	Avatars
Badges	Difficulty	Meaningful stories
Leaderboards	Social Games &	
Performance Graphs	Teamwork	
Virtual Gifts & Items		

4.2.2 Older adults' technology adoption and knowledge transfer

Evidence shows that the rate of adoption of technology among older adults always remains at a lower level compared with the younger generation (Choudrie et al., 2020). Despite research acknowledging the importance of digital technology in supporting older adults' daily living and improvement of their life quality (Peek et al., 2016), a big challenge arises in the adoption and appropriate use of technology in their life.

Bradley et al. (2010) proposed a model of learning difficulty for novice users of digital technology as shown in Figure 4.2, which has been used in their later study (Barnard et al., 2013) to explain older adults' technology learning process, which provides insight into the knowledge transfer design for older adults. It suggests that to facilitate and encourage the adoption of technology, both the perceived and actual 'max learning pain' should be made

as low as possible, thus rendering the learning of digital technology easier. In addition to learning difficulty, Peek et al. (2014) found a positive relationship between the need to use technology and its effective utilization, where people are more likely to use a technology only if they recognize the need. While Hill et al. (2015) argued that in many cases, even if older adults acknowledge the benefit of a new technology such as the convenience of online payment and mobile payment, it is difficult to supplant the traditional way (i.e., cash or bank cards) among older adults. Broady et al. (2010) proposed the idea of selective technology use, inspired by Baltes' (1987) concept of selective optimization with compensation. They debate whether older adults are not necessarily negatively disposed to technology, but to cope with their declined cognitive capability, they are selective in what they believe is both beneficial and necessary to their life. As a result, stronger motivation is needed to encourage older adult technology adoption.

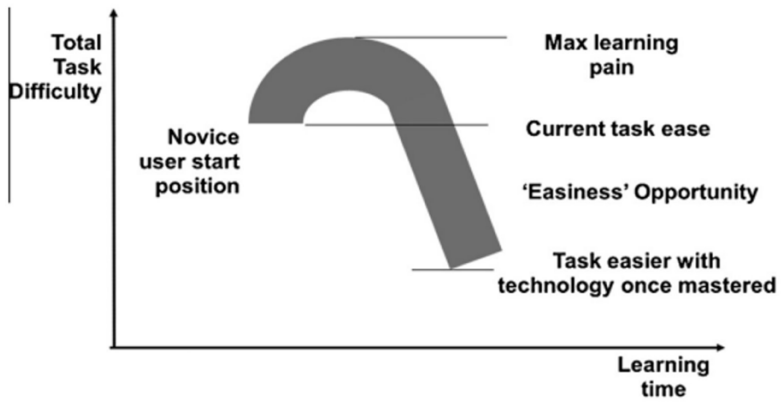

Figure 4.2 Abstracted model of learning difficulty perception for novice users of digital technology (Barnard et al., 2013)

Despite the difficulties involved and barriers to older adults' technology adoption having been highlighted, the technology knowledge transfer behavior of older adults has been rarely studied. Some researchers suggest that knowledge transfer activities, such as guidance, training, or tutorials may reduce older adults' technology anxiety. However, these insights have emerged mostly from studies investigating factors determining older adults' technology usage behavior or understanding their perception of technology as suggestions, rather than the solutions. Only a few studies have been found to investigate how to properly design the supporting service for helping the technology knowledge transfer to older adults. For instance, Leung et al. (2012) proposed a blend of methods that supported older adults to use mobile devices, including trial and error, manual, internet,

help features, step-by-step instructions, note taking, demonstrations and practice, feedback and support of single learning or in combination with one or more others. Nevertheless, most methods for technology knowledge transfer are generalized, and older adults' technology adoption is still poor. As a result, there is an urgency to develop an effective older-adult-oriented approach to promote their technology adoption.

For different purposes, there are various models and framework for knowledge transfer. Ward et al. (2009), through a thematic analysis of 28 models, identified five commonly used components in the knowledge transfer process, which are: 1) problem identification and communication, 2) knowledge development and selection, 3) analysis of context, 4) knowledge transfer activities or interventions, and 5) knowledge utilization. The first three components serve knowledge generation. The fourth is the transfer activity or intervention itself, which has two main types: distribution-type interventions and linkage-type interventions. The last component is the actual knowledge use.

4.2.3 Design for older adults

The literature and theories discussed above mainly focus on older adults' psychological aspects and a small part of cognitive ability, while physical changes should be addressed as well to achieve a successful design for older adults (Carr et al., 2013). Wildenbos et al. (2018) classified the technology adoption difficulties for older adults into four categories. In addition to the motivational barriers discussed in the previous section, cognitive barriers, physical barriers, and perception barriers also significantly influence their technology usage. Nunes et al. (2010) noted that the aging process brings remarkable changes to the human perceptual system that are rooted in physical and perception changes. They highlighted the declines in vision, hearing, and motor systems as the key physical changes, and perception declines in receiving or interpreting sensory information from the environment, which impact on the interaction of older adults with technological products. They further argued that limitations on cognitive ability, including changes in processing, understanding, or interpreting information, are also essential to create an older adults' satisfactory human–computer interaction.

With the unique characteristics of older adults, user-centred design principles need to be addressed to guide the design process. User-cetered design emphasizes developing interactive system that prioritize users and their needs, with the application of ergonomic criteria and usability knowledge (Chammas et al., 2015). Liu et al. (2021) proposed a set

of recommendations for elderly-friendly interface design in response to older adults' changes. To cope with vision impairment, larger buttons and text size and using color effectively are required, and the provision of audio alternatives is also a good suggestion while considering older adults' decline of hearing; the audio volume needs to be ensured, and a vibration during each auditory tone can be added. For motor coordination problems, simple gestural interactions and minimized text entry are effective methods. In terms of cognitive deterioration, keeping things simple and direct is critical, including a simple and consistent layout, simple and clear navigation, multimedia presentation, and easy-to-understand content. Morey et al. (2019) shared similar ideas with Liu et al. (2021) in their study on the design of mobile health apps. In addition to the recommendations mentioned above, they suggested an app design for older people to improve the access to helpful information and provide detailed user instructions to aid their use and the helpful information should be clearly labeled and easy to access. These findings align with user-centered design's focus on user capabilities (Keinonen, 2008). Moreover, recent studies demonstrate co-design with older adults yields more effective solutions. Doroudian et al. (2018) explicates that the involvement of older people in design process made their game better tailored to older adults' needs. Le et al. (2014) refined their prototype of a visualization of a smart home system based on the knowledge obtained through involving older users.

Moreover, older adults constitute a heterogeneous group, with difference skill levels, learning paces, user preference, and cognitive and physical condition, therefore, personalization may address key barriers for older adults' adoption by tailoring content, interfaces, and challenges levels to individual needs. Personalized elements, such as adaptive difficulty levels, customized rewards, or role-based narratives, can sustain motivation and reduce frustration (Kramer et al., 2000). Therefore, incorporating personalized design for older adults may generate more effective and more engaging system.

4.3 Design framework

4.3.1 Relationship among gamification, technology knowledge transfer, and older adults

Gamification, technology knowledge transfer, and older adults are three key elements in this study. According to Wilson et al. (2015), a gamified system involves three essential components: a non-game task, a user, and a set of game design elements (GDEs), which

correspond to the three elements in this study. Figure 4.3 demonstrates the relationship among user, non-game task, and GDEs. In Wilson et al.'s (2015) view, the relationship between user and task is the reason for proposing a gamified system. They summarized the relationship as 'valuation,' where the more the user values the task, the more effective the gamification is. The relationship between user and game design elements is 'motivation,' in which users are motivated and engaged by GDEs as discussed in the aforementioned literature. In terms of the relationship between GDEs and task, the fundamental aim is the task itself, and the role for gamification is to establish a game-like experience to reinforce the value of the task. This relationship is called 'meaning.'

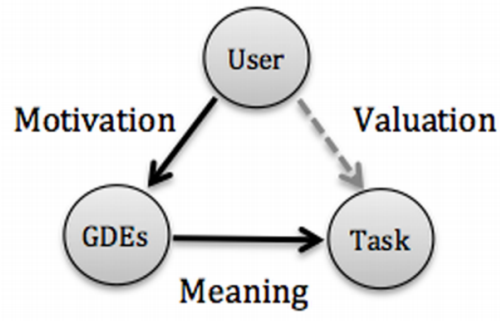

Figure 4.3 Relationship-based model of effective gamification

Applying the relationship model to this study, this study aimed to develop a gamification approach for older adults to promote technology knowledge transfer and their effectiveness and motivation to adopt technology. In fact, the three elements all have a specific design concept centered on themselves. The combination of knowledge transfer process with the gamification design concept has been widely practiced in young adults' education and employee training. Research on knowledge transfer for older people can also be commonly found in knowledge transfer studies, particularly for younger age and older age comparison. Studies on adopting the gamification design for older adults are few while its feasibility has been examined, whereas there is no study integrating these three design concepts together to establish a more comprehensive design framework to better serve older adults technology adoption with gamification tools.

Our study differs from others in several ways. Firstly, this study proposed a theory-based design framework. Not only were the majority of previous studies not grounded in theory, but even the studies that built on theory mainly focused on the popularized theory such as self-determinations theory and flow theory, with limited the consideration of the context itself (Huang & Hew, 2018). Secondly, narrowing down into the gamification study

of older adults, there is no design framework for older adults that has been developed based on theories related to older adults. Most of the existing studies still followed the generalized guide. Older adults' attitude and preference toward game features are different from that of the younger generation; therefore, our study integrated theories of aging, while developing an older adults' specific design framework. Moreover, aside from stereotypes, our study does not treat older adults as a distinct group from other age groups, but rather highlights the changes that come with age and incorporates these factors into the framework design.

4.3.2 Design framework of the gamification approach for older adults' technology adoption and knowledge transfer

As suggested in the literature, a competent gamification design should fit the context and characteristics of its target users (Behl et al., 2022). To overcome a salient weakness in the majority of studies—which typically analyze gamification features already embedded in the pertinent products or services—we therefore developed a tailor-made gamification approach for technology knowledge transfer, incorporating the consideration of the distinctive characteristics of older adults. Figure 4.4 demonstrates our design framework of the gamification approach for older adults' technology adoption and knowledge transfer, which integrates technology knowledge generation, older adults centered design, and gamification design together. The technology knowledge generation follows the commonly used knowledge transfer process, which includes problem identification and communication, knowledge development, and the analysis of context. The problem identification and communication describe a process to identify the user needs and communicate with decision makers and researchers, for building a case for action (Havelock, 1969). It is described as objectives' identification in this framework. The MDA framework was used for gamification design, which provides us with carefully designed game features in a non-gamified technology generation process to form a more engaging system. Finally, four older adults' barriers to technology usage identified in the literature were applied for older adults centered design concepts, thereby allowing the system to be tailored more effectively to older adults. All three design concepts were simultaneously engaged in the whole design process. User interface (UI)/ user experience (UX) design are responsible for ensuring seamless, functional, and user-friendly interactions among the three core design concepts: gamification, technology knowledge

generation, and older adult-centered design. It focuses on the following aspects: 1) interactivity, which defines how users interact with the system; 2) usability, which ensure the interface is visually appealing, easy to navigate, and tailored to older adults' needs therefore to enhance usability; 3) experience, which focus on creating a positive user experience; 4) consistency, which ensure applying consistent design patterns to reduce confusion and allows the system can adapt to future updates or changes.

Moreover, during the design process, some design constraints need to be addressed, which include (1) older adults' usage constraints, including cognitive and physical limitations (e.g., memory decline, reduced dexterity, and sensory impairments); (2) technical restrictions, where the system needs to be operated in mobile phone; (3) resource limitations regarding cost, human resource, and technology; and (4) socio-cultural factors such as traditional payment habits, lifestyle beliefs, and language barriers that influence user behavior. These constraints significantly impact system design and must be carefully considered throughout the development process to ensure usability and adoption among elderly users.

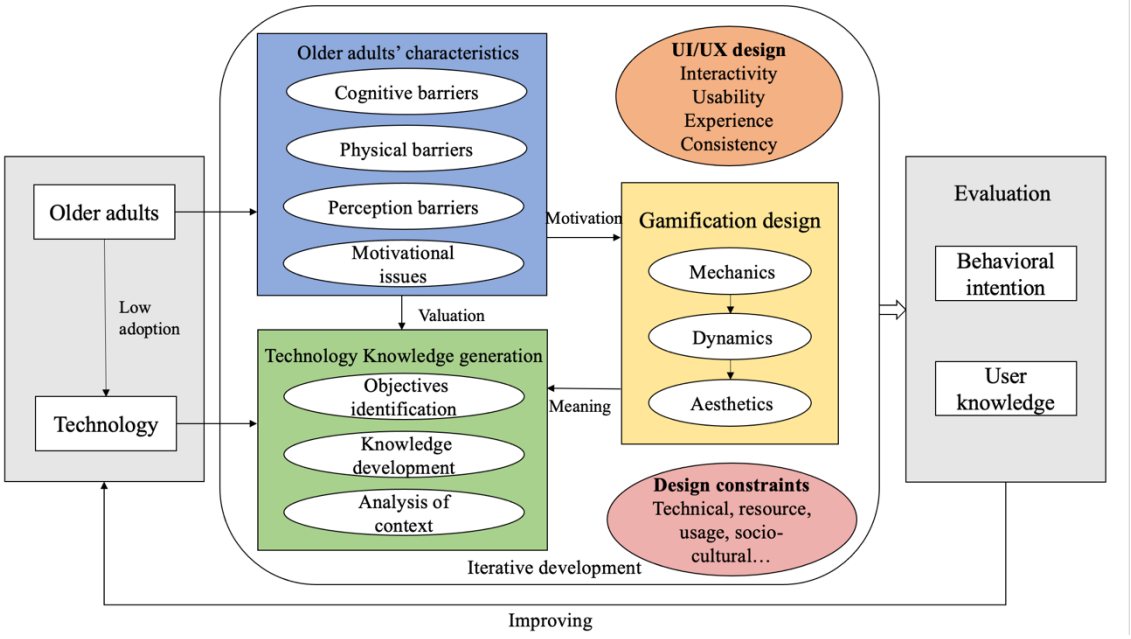

Figure 4.4 Design conceptual framework of the gamification approach for older adults' technology adoption and knowledge transfer

Informed by the design concept framework, we recommend a six-phases design procedure (4DIE) (Figure 4.5), including discover (D), define (D), design (D), development (D), implementation (I), and evaluation (E). It is adapted from ADDIE design

framework for instructional system design. Taking a consideration on commonly used user-centered design process (ISO13407) (ISO/IEC, 1999) and some gamification design frameworks (Antonaci et al., 2018; White et al., 2016), this framework divides the analysis phase into two phases: discover and define, which allows the designers have a more logical design concept with a clearer delineation of the application context and its derived design objectives. This framework makes it possible to develop a theory-driven, systemically, and empirically evaluated older adults-centered gamified system for technology knowledge transfer (Hevner et al., 2004).

The Discover phase involves understanding the application context and older adults' need through literature reviews (Chapter 2), market research (Chapter 3 macro study), surveys (Chapter 3 micro study). In Define, clear learning objectives and gamification goals are established. The design process adopts mental iteration, a cyclical approach where the system is continuously improved by analyzing problems, generating ideas, composing solutions, and evaluating outcomes. According to Jin and Chusilp's (2006) iteration classification, this approach aligns with constrained creative design. Improvements are made cyclically until the system meets design criteria. Finally, Implementation involves deploying the finalized system to older adults and feedback collection. Moreover, the system is monitored by designers to ensure smooth operation. The collected feedbacks are evaluated to assess the effectiveness of the developed gamified system.

The framework emphasizes user-centricity, iterative refinement, and the integration of gamification with accessible technology.

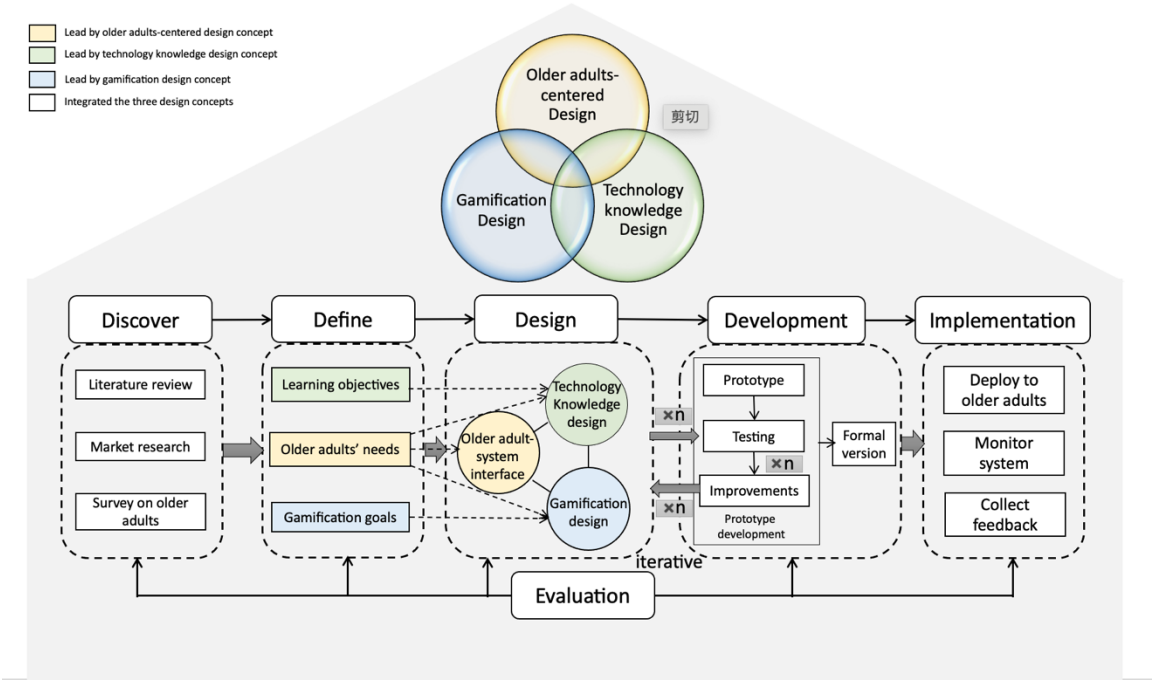

Figure 4.5 4DIE design procedure for older adults tailored gamification system of technology knowledge transfer

4.4 Demonstration of the proposed gamification approach development

4.4.1 Motivation and case selection: mobile payments in Hong Kong

Mobile payment systems have burgeoned internationally since their introduction. In many places, they are now replacing traditional payment methods. Traditional cash payment is universally accessible, easy, and private but insecure, unhygienic, and impractical for large transactions. Therefore, e-payment methods start to capture the market. E-payment improves speed and security with contactless transactions (Fatonah et al, 2018). Card payment offers broad acceptance and while may incur fees and remain vulnerable to skimming. Mobile payment provides the fastest and most secure transactions. It eliminates the need to carry physical cards or cash and offer automatic digital records (Bezhovski, 2016). Table 4.2 compares these three payment methods.

Table 4.2 Comparation of different payment methods

Feature	Mobile payment	Card payment	Cash
Convenience	✓ Fast (NFC/QR codes) ✓ No physical card needed	✓ Fast (tap/swipe) × Requires carrying cards	× Requires exact change ✓ No technology needed
Transaction Speed	✓ Instant (1-2 seconds)	✓ Fast (3-5 seconds)	× Slow (counting/change)
Record-Keeping	✓ Automatic digital records	✓ Bank statements	× Manual tracking required
Accessibility	× Requires smartphone	× Requires card	✓ No prerequisites
Hygiene	✓ Contactless (no touch)	× Card insertion/swiping	× High germ transmission risk
Security	✓ Tokenization ✓ Biometric authentication	✓ EMV chip/PIN protection × Vulnerable to skimming	× Easily lost/stolen × No fraud protection

Mobile payments are especially prevalent in Hong Kong, spurred on by the consumption vouchers scheme for eligible residents introduced by the HK government to boost local spending and stimulate the economy. In 2021, the HK government began disbursing the vouchers in electronic form, signaling its intention to promote e-payment practices in Hong Kong. From their launch until the time of this study, the consumption vouchers were distributed via six channels: AlipayHK, Tap & Go, WeChat Pay HK, Octopus, BoC Pay and PayMe. AlipayHK, according to the survey conducted by HKIBS (2021), is the most popular channel among younger respondents (18–45 years old), accounting for 40 % of respondents, with the percentage decreasing with age, with only 23 % of respondents aged 66 or above choosing AlipayHK as the collection channel. This result is corroborated by research published in AlipayHK's consumer report in which it was found that the acceptance rate of its app has a fractal decline among people aged above 50 (Hong Kong Productivity Council, 2019). Older adults prefer to receive vouchers via Octopus card, which is a smart card initially used for public transport and that has played a significant role in the development history of Hong Kong's e-payment systems. Despite the dominance of AlipayHK for mobile payments by the younger generation, the traditional Octopus card still occupies a prominent position in Hong Kong as an e-payment method (Chen and Chan, 2014b), especially among older people.

Recognizing the importance of contemporary innovative technologies for fast e-

payment transactions and considering the impact of the “aging in place” phenomenon of older adults, it is appropriate to investigate the factors affecting the technology usage and adoption behavior of older adults in the field of mobile payments. The case of AlipayHK, in Hong Kong, is ideal for this purpose.

4.4.2 Technology knowledge generation

The gamification system was developed by Evkworld, a visual game development engine. This gamification system included two main parts, the learning part and the practicing part. The technology learning part of the framework was firstly constructed with objectives appropriate for improving older adults’ understanding and knowledge of the AlipayHK payment system. The practicing part aimed to transfer the knowledge in practice and test the knowledge received by older adults.

The knowledge development was built on the instruction provided by the official website of AlipayHK. Figure 4.6 demonstrates the original instruction for the ‘Top up with cash’ function, which consists of textual descriptions and relevant diagrams. For some functions, such as ‘EasyGo’ (Figure 4.7), only textual descriptions have been provided on its official website, which were not friendly to older adults.

Figure 4.6 Instruction of ‘top up with cash’ provided by AlipayHK’s official website

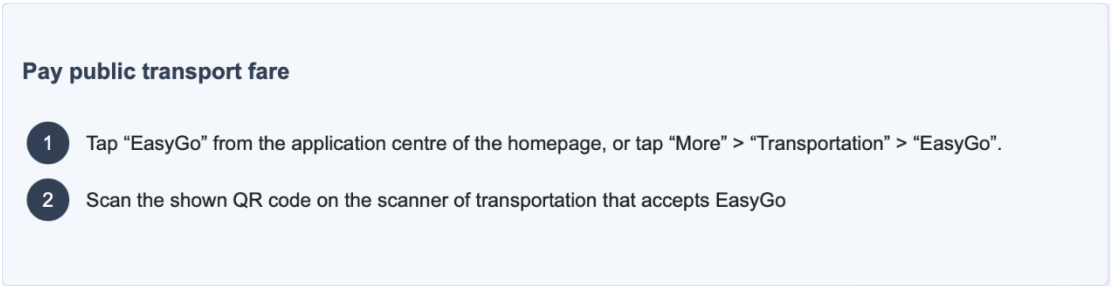

Figure 4.7 Instruction of ‘EasyGo’ provided by AlipayHK’s official website

As a result, four commonly used functions of AlipayHK in daily life were selected as the content for knowledge development, namely “top up,” “scan,” “payment,” and “EasyGo.” Considering older adults’ characteristics, we provided step-by-step guidance that simulated the actual interface, as shown in Figure 4.8. In this way, older adults did not need to further process the text-based instruction into action, but rather follow the guidelines directly to perform actual operations. Additionally, it allows repeated learning. Creech and Hallam (2014) argued that to foster autonomy and self-regulated learning, more supportive ways are necessary to act as ‘scaffolding’ to help them achieve challenging yet attainable outcomes.

After analyzing the context, older people prefer things that reflect reality rather than abstractions and find it easier to accept what they are familiar with (Leonardi et al., 2008). In order to make it closer to a real tutorial, we added some school element cartoons to the content (Figure 4.9). The gamified material was developed for application in mobile phones, which is also the AlipayHK operation platform, supported by two languages, English and Chinese (Traditional).

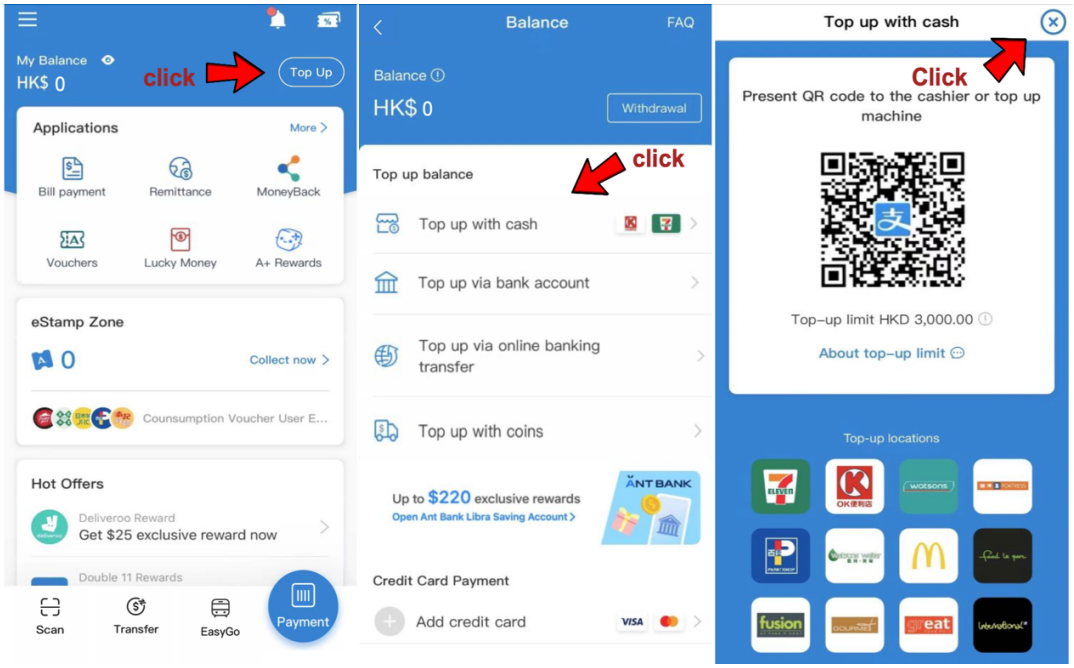

Figure 4.8 Guidance of “top-up”

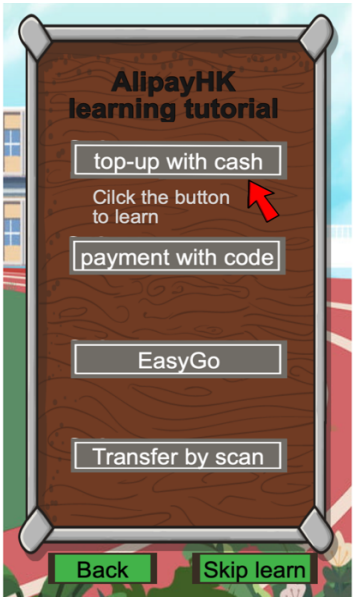

Figure 4.9 Tutorial content page

4.4.3 Gamification design

The gamification design elements were incorporated into the system following the knowledge development context and paying close attention to the distinctive characteristics of older adults. In accordance with the MDA framework, game elements were added mainly into the practicing part. In this part, we created some game-like mission completion tasks, embedded into daily activities such as “working,” “dining,” and “site visiting” (Figure 4.10, Figure 4.11). Each task corresponded to one payment function. In this way, this system did not simply examine whether the older adults knew how to operate these functions, but rather set the functions in real usage scenarios to ensure mastery of the applications by older adults in daily life.

Figure 4.10 Homepage of practice part

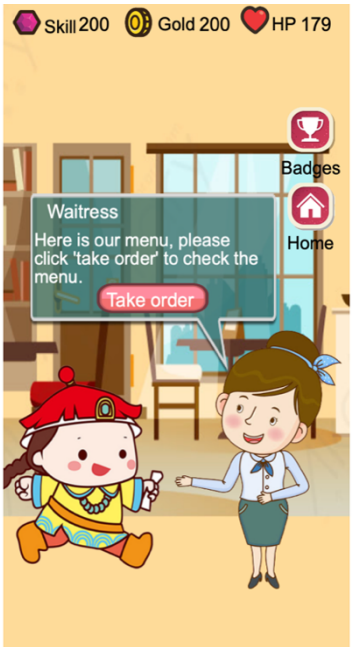

Figure 4.11 Dining activity

After having successfully accomplished a task, users receive a badge representing the payment function for that task, and when all the badges have been collected, the mission is deemed successful (Figure 4.12). In addition to game mechanics, we introduced three game variables—"skill point", "gold," and "health point"—into the system to increase the dynamics. The "skill point" represented the correctness of operation, with points being deducted when errors were made. The "gold" acted as the currency in the system, which was a necessary element in the transaction process for a payment task. The "health point" measured the time taken by the user, decreasing as the remaining time decreased.

Finally, the user's performance, including both accuracy and time taken, was indicated on a leaderboard. Through the game mechanics and dynamics, experiences of challenges, discovery, expression, and fantasy were generated, thereby evoking the aesthetics. Some researchers (Hoshino & Mitani, 2018; Ijsselsteijn et al., 2007) have highlighted the importance of positive feedback for older adults' game design, as a lack of confidence is a key factor inhibiting older adults' play. We therefore introduced a feature into the game whereby users were immediately notified of a payoff when an operation was conducted correctly. They were notified not only with badges and reward points, but also with positive feedback and encouragement (Figure 4.13).

Figure 4.12 Mission complete

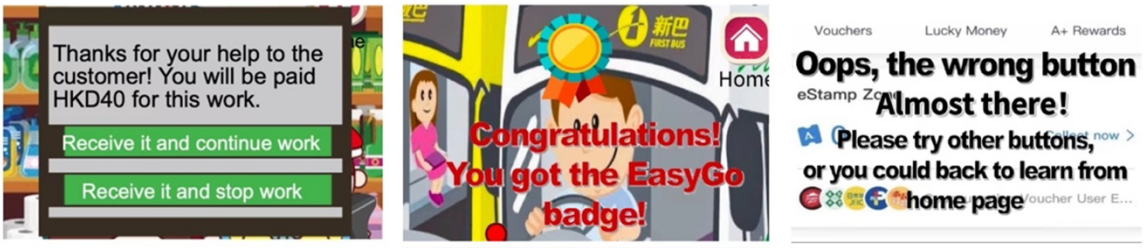

Figure 4.13 Feedbacks

Moreover, to improve the aesthetic experience of the older adults and create a more game-like experience for them, we designed a full storyline and architecture for the gamified system rather than simply add gamification elements into the non-gamified learning system. This feature was informed by the work of Cota et al. (2015) who have shown that older adults pay more attention when narratives are included in mobile games. We set an ancient emperor as the main character, who traveled to the modern cashless society. His mission was to master the four AlipayHK payment functions for successful living in modern society. This storyline was designed with two primary considerations: firstly, to avoid stereotypes, selecting a non-relevant character in a real-life scenario, instead of an older adult; and, secondly, creating a more entertaining story context and a greater sense of accomplishment from success.

4.4.4 Older adults' characteristic consideration

To ensure the system was older-adults-friendly, the physical context and cognitive

context of older adults, as well as mobile infrastructure, were carefully considered in not only the technology knowledge generation and gamification design, but also the whole system design. The visual design included large text size, simple icons, and sufficient space. For color selection, we applied high-contrast color combinations to fonts, graphics, and the background to ensure perceptibility and readability. Regarding the content, we ensured that all the expressions in the system—including instructions, navigation, dialogues, questions, and feedback—were designed to render the system simple, clear, and unambiguous. Sound and tactile feedback were provided when an icon was pressed to ensure that older adults know that the icon had been pressed successfully.

To assess the effectiveness of gamification in improving technology adoption among older adults, this study intentionally excluded personalization to maintain methodological rigor, despite its potential to create tailored systems. While personalized elements could enhance individual engagement, their inclusion would introduce confounding variables that influence user performance. By standardizing the design, this approach isolates the effects of gamification mechanics, ensuring clearer attribution of outcomes to the intervention rather than individual adaptations.

4.4.5 Iterative development

We developed the system through an iterative process of prototyping, testing, and improvements in three phases: beta testing, first-round user testing, and second-round user testing. Beta testing has been conducted by developers of early versions of the system to examine errors, bugs, crashes, and layout issues and heuristic evaluation has also been carried out to inspect the interface design. We incorporated feedback to fix bugs and improve the fluency for subsequent iterations.

In the first-round user testing, we invited the six older adults who had participated in the interview at the discovery stage to provide feedback on the system's functionality and aesthetics. They were considered as 'lead users' of mobile payment technology. Venesz et al. (2022) suggest that only lead user, experience new needs before the rest of the marketplace, can provide accurate requirements for product development. When these users are systematically engaged in design processes, the resulting better products development. Therefore, followed the lead user identification framework from Pajo et al. (2015), we recruit our lead users. The lead users need to meet four criteria: firstly, the lead user should have representativeness of target audience; secondly, they need to have

willingness to share ideas, therefore, they can articulate their thoughts, experiences, and ideas clearly; thirdly, they need to open to exploring new ideas; fourthly, they are required to comfortable with technology and have experience using similar systems or apps. With these requirements, the lead users for first-round user testing have been selected. They were asked to test whether the system met their needs and to provide suggestions on possible improvements. The objective was to obtain an indication that the system has potential to be accepted and used by the target groups.

In the second-round user testing, we recruited another five older adults to participate in systemic analysis with a focus on usability through a think aloud protocol, which is a well-recognized method in software development for usability testing (Boren & Ramey, 2000). Previous studies suggested that four to five people are basically sufficient for the identification of 75% of usability issues for physical products and simple system (Nielsen, 1994). For our simple gamification system for older adults' AlipayHK learning, Nielsen's proposition appears reasonably applicable. After a short introduction to the system, the participants were asked to explore the system independently and complete all the tasks, then verbalize their thoughts and reactions as they navigated through the system. With the purpose to better observe the natural flow of system usage, the researchers remained silent during their exploration, speaking only when they issued questions.

Through the iterative development process, some improvements were made. For instance, we gave users opportunities to go back to the instructions page for a reminder after they had entered into the quizzes phase, and in our early design, we set a 'school' icon together with a short description to indicate this function as shown in Figure 4.14. Users noted that the 'school' icon was not straightforward and confused them; therefore, in response, we modified it to a button called 'go back to learn' to make the meaning clearer. To better imitate the real 'top up with cash' and 'payment' process, a scan animation (Figure 4.15) has been added to the gamified tasks.

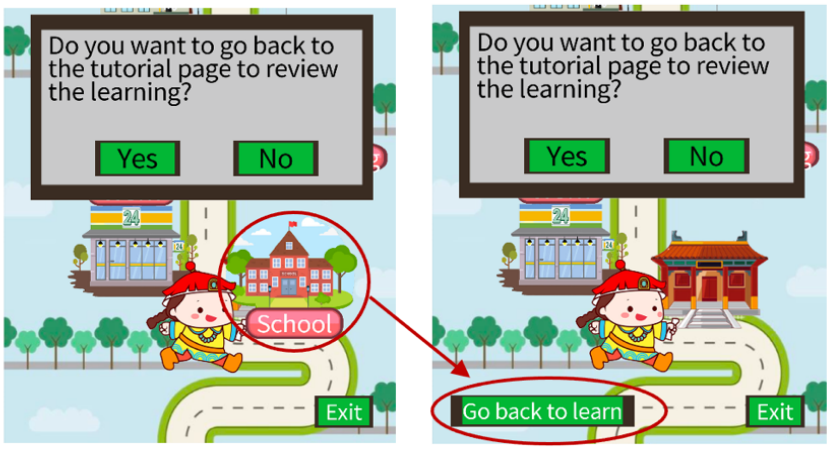

Figure 4.14 Change on the way back to instruction

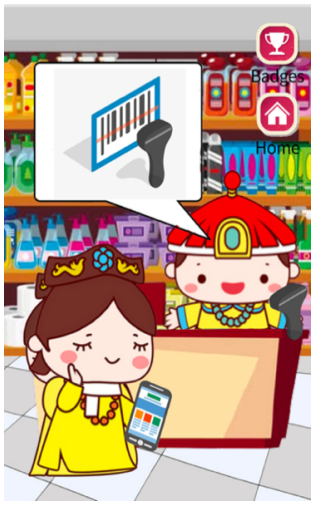

Figure 4.15 Scan animation

4.5 Summary

Since this study was an initial exploration of developing a centered gamification design framework for older adults, systematic research was a critical component of the development process. Guided by the existing literature, the principles for gamification design, technology knowledge generation, and older adults centered design have been determined to underpin the gamification approach. Grounded in these theories, an iterative design framework has been proposed and the specified process of how the framework can be implemented to construct a gamification system has been demonstrated through an experimental study.

4.5.1 Implications

The proposed gamification framework advances the field of study by introducing a theory-driven, aging-specific design framework that addresses critical gaps in prior research. It demonstrates significant theoretical and practical novelty as the first theory-grounded gamified learning design framework specifically tailored for older adults.

From the theoretical perspective, it filled the gaps in gamification research from two aspects. Firstly, prior gamification studies, even those claiming theoretical foundations, often default to generic motivational theories without a full contextual consideration. Our framework breaks this pattern by fully incorporating the contextual factors and integrate gerontechnology principles, aging-specific theories, and gamification theories together. We moved away from universal gamification design methods and non-theory-grounded processes, providing a rationale for how learning and motivation theories related to older adults can guide gamification design. This is the pioneering study that incorporate both task-related and user-related theories in gamification design. Secondly, it is also one of the first to apply age-related theory to gamification research, which addressed the unique cognitive, perception, motivation, and physical needs of older adults. This approach fills a critical gap in gamification research, which has largely overlooked demographic-specific design while overgeneralizing findings from younger populations. Thirdly, it challenged stereotypes that isolate older adults from other age groups. Instead, older adults' preferences, such as heightened sensitivity to failure and need for positive encouragement, are systematically addressed.

During the gamification system design and development process, some lessons were learned which might be helpful in future gamification design for older adults, not only for technology adoption. Firstly, similar to the younger generation, older adults do enjoy and can be motivated by games and game elements and they share in common most preferences and perceptions of gamification features. Despite older people suffering from age-related changes, they should not be isolated too completely from people in other age groups. Secondly, compared with young people, older adults may be more afraid of failure; therefore, positive feedback and encouragement are necessary in a gamified system. Thirdly, detailed navigation can help older adults exercise better handling of the system. Moreover, Kano Model may incorporate when developing gamified materials for older adults in future work, which offers a structured framework for evaluating how different product or service features influence user satisfaction, enabling more targeted and effective

design decisions (Sauerwein et al., 1996).

Practically, our study provides inspirations for gamification research in other scenarios. Our work challenges the prevailing assumption that gamification frameworks are universally applicable. Instead, we balance universality and specificity and advocate for theory-driven, context-sensitive design across domains. Gamification is not a one-size-fits-all approach that can be applied to all situations; each situation is unique and should be tailored to the context, the task, the system, and the target users. Moreover, we emphasized methodological rigor, explicit linkage between theory, design, and evaluation. This study demonstrates a process by which theory-driven gamification design can be systematically developed and evaluated, including how to select a motivational theory that is appropriate for the gamification design context, how a gamification design model can be step-by-step applied in practice, and how to assess the effectiveness of the developed system, offering a replicable paradigm It encourages more customized approaches with theoretical underpinning applied in different scenarios, rather than a generalized model or framework, which is more promising to generate satisfactory results.

In this study, we focused on the development of a design framework and the demonstration of the gamification system construction for older adults' technology adoption and knowledge transfer. This paradigm shift from generic to tailored design, not only hold promise for enhancing engagement in older adults' technology adoption, but also inspire design in diverse scenarios. The performance of the framework and the proposed system will be evaluated in the next chapter.

Chapter 5 Performance analysis of proposed gamification approach through extended Technology Acceptance Model

5.1 Introduction

In the Chapter 4, we tailor-made gamification system for a mobile payment platform, i.e. AlipayHK, based on an established gamification approach, taking in to account the distinctive characteristics of older adults. In this chapter, we conducted research analyzing the performance of gamification approach as the centerpiece of a servitization strategy for improving older adults' technology adoption and knowledge transfer by exploring the application of the proposed gamification system of AlipayHK among older adults in Hong Kong. The degree to which older adults' understanding of mobile payment systems could be enhanced, their intention to adopt new technology could be strengthened, and knowledge more effectively transferred to them, have been tested through gamification. The effectiveness of this approach was assessed by adopting a one-group pretest-posttest experimental design, incorporating a modified version of the established Technology Acceptance Model (TAM) extended with gamification features.

This study differs from previous research in several ways. Firstly, in contrast with many gamification studies on technology acceptance that measure outcomes only after the experiment has been conducted, a one-group pretest-posttest design was adopted here. As suggested by Dimitrov and Rumrill Jr (2003), a single test design is poor for guarding against assignment bias, which in turn weakens the power of the statistical results, while the pretest-posttest method provides researchers with a way to filter out experimental noise. Secondly, gamification results depend highly on the experimental context and the target user (Koivisto & Hamari, 2014). In this study, instead of using generalized game elements or gamification features already existing in the targeted system, we developed a tailor-made gamified system grounded in theory specifically designed for older adults. Thirdly, to better examine the effects of gamification on older adults, we applied an extended Technology Acceptance Model by adding user knowledge and gamification-related constructs to the model, thus providing a paradigm for future gamification studies related to technology acceptance and adoption.

Our study is thus a pioneering examination of causal relationships associated with user knowledge and gamification. Gamification is an approach to "edutainment" with extensive application in educational, learning, and performance-improvement contexts (Ma et al.,

2011).

We make a fresh contribution to gamification research by, among other things, augmenting the study of users' acceptance of gamification, or its impact on users' behavioral intentions, by examining users' acquisition of knowledge and the improvement of their non-game performance through gamification. Our model thereby seeks to paint a more holistic and multifaceted picture of the goals and impacts of gamification in educational and practical settings.

5.2 Theoretical framework and development of hypotheses

In the introudction just summarized, we confirmed the significance of investigating the impact of gamification on older adults' technology adoption, and identified the research gap to be filled, which is to examine the effectiveness of gamification in improving older adults' technology adoption and knowledge transfer. To pursue this goal, we developed a theoretical model—described below—combining the established technology acceptance model (TAM) with gamification-related constructs and user-knowledge constructs.

Understanding users' intentions and behavior concerning technology acceptance and adoption is a long-standing and critical topic in the digital world. Our decision to draw upon the TAM (Davis, 1989) as the theoretical basis for our framework was based on several considerations. Firstly, the TAM is arguably the most widely acknowledged and influential model in the field of technology acceptance and adoption (Lian & Yen, 2014; Schöpfel & Azeroual, 2021). Its robustness in explaining acceptance and usage behavior has been demonstrated through numerous studies. Secondly, the TAM has been widely adopted in both gamification research (Wang & Sun, 2016; Wong et al., 2021; Zheng, 2019) and research on older adults (Chen & Chan, 2014b; Šumak et al., 2011). As stated by Guner and Acarturk (2020), the strength of the TAM is its predicting power in different contexts, with different groups of participants and different technologies explored. Considering that the study of gamification implications for older adults is a newly explored research direction, the TAM's ability to adequately explain adoption behavior is particularly valuable. Furthermore, the original TAM framework offers flexibility for modifications and extensions. It has been found that extending orthodox TAMs by incorporating contextual constructs increases the explanatory power of the model and enables a more nuanced understanding of the behavior of the target audience within specific contexts (Martín-García et al., 2022; Verdegem & De Marez, 2011). The TAM used in this study

therefore integrated context-specific constructs concerned with gamification for technology adoption by older adults.

To achieve superior assessment of the effectiveness of gamification than existing studies that rely upon a single-phase investigation of outcomes, we adopted a pre-experimental/post-experimental design to evaluate older adults' behaviors and intentions before and after gamification intervention. Figure 5.1 and Figure 5.2 illustrate the theoretical frameworks for pretest and posttest from the postulated relationships among constructs.

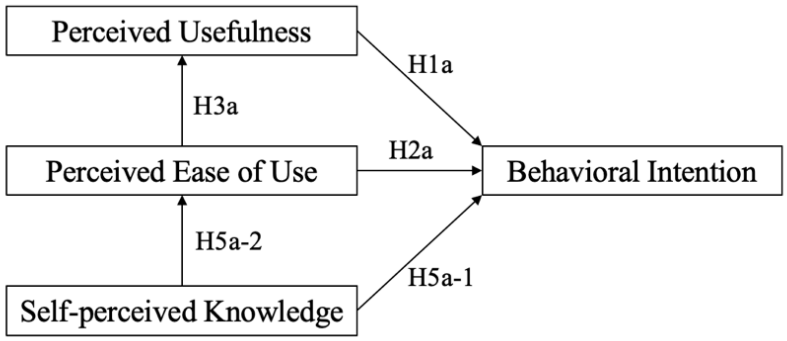

Figure 5.1. Theoretical framework for the pretest

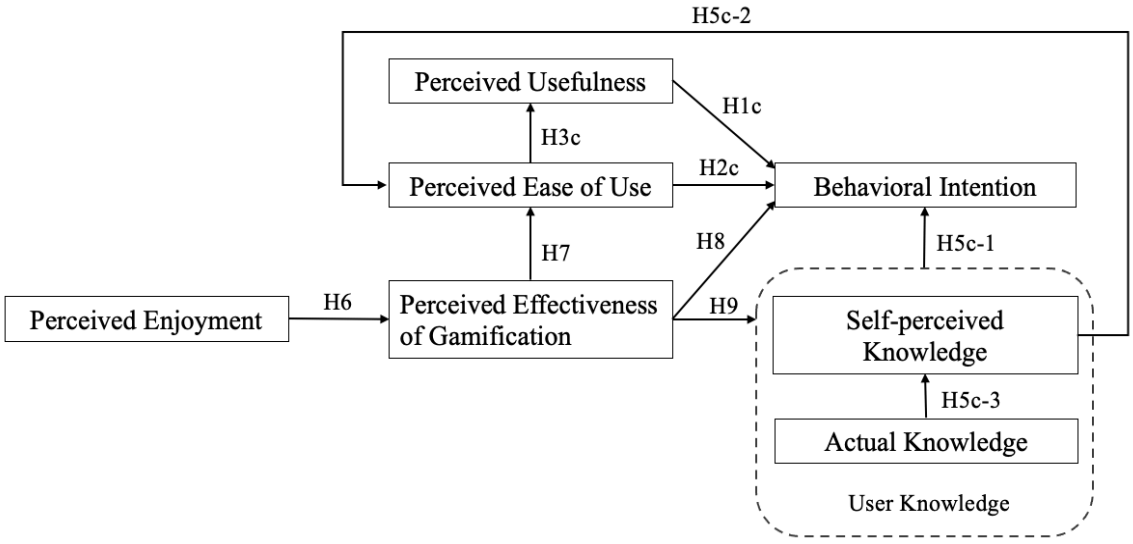

Figure 5.2 Theoretical framework for the posttest

5.2.1 Hypotheses development for pre-test

5.2.1.1 TAM constructs

The TAM embodies the theory that the acceptance and usage of a technology is influenced by two major beliefs: perceived usefulness (PU) and perceived ease of use

(PEOU). PU is defined by Davis (1989) as "the degree to which a person believes that using a particular technology would enhance his or her life" and PEOU as "the degree to which a person believes that using a particular technology would be free of effort." Venkatesh et al. (2003) explained the related concept of behavioral intention (BI) as "a person's subjective probability to perform a behavior." Moreover, PEOU has been considered as a determinant of PU (Pai & Huang, 2011), which assumes that with all else being equal, users consider a technology to be more useful when using it requires less effort (Davis, 1989).

Prior research on mobile payment systems has empirically validated the predictability of the TAM in mobile payment usage (Türker et al., 2022). In a more pertinent scenario, a study conducted by Li et al. (2019b) with Chinese audiences, generated evidence that users' willingness to use Alipay was significantly influenced by PU and PEOU. It has been found that older adults confer greater utility on technology when it actually does have the capacity of improving their independence and quality of life (Steele et al., 2009). Along with utility, other research has confirmed the importance of ease of use for older adults in ensuring that the benefits of technology may be realized (Lee and Coughlin, 2015). As a result, it is postulated that before gamification intervention:

H1a. Perceived usefulness has a positive effect on behavioral intention towards mobile payment usage by older adults.

H2a. Perceived ease of use has a positive effect on behavioral intention towards mobile payment usage by older adults.

H3a. Perceived ease of use has a positive effect on perceived usefulness of mobile payment methods for older adults.

5.2.1.2 User Knowledge (UK)

In addition to the factors identified in the TAM, user knowledge has been identified as an important factor affecting people's intentions to use technology, and this is particularly true for older adults (Aggarwal et al., 2015). According to Walsh and Callan (2011), people's perception of technology is founded to some degree on their experience and knowledge. Moreover, the causal relationship between knowledge and adoption behavior appears to be stronger for older adults, since knowledge of technology is more likely to be negatively related to age. Thus, in this study, user knowledge is included as a determinant

of older adults' technology adoption.

To assess user knowledge, many studies employ the single construct of self-perceived knowledge (SPK), which refers to "a person's estimate of how much he/she knows or has learned about the technology" (Aggarwal et al., 2015). From the perspective of social cognitive theory, Bandura and his colleagues (Bandura, 1986; Bandura and Walters, 1977) have posited that people's expectations of their competence determines what decisions they make, how much effort they dedicate, how long they persevere, and what strategies they employ to cope with challenging circumstances. Aggarwal et al. (2015) suggest that users' self-perceived knowledge has much higher predictability than actual knowledge in the initial evaluation of technology adoption intentions.

Moreover, researchers found a linkage between self-perceived knowledge and perceived ease of use in the TAM constructs. Venkatesh and Davis (1996) suggested that the self-efficacy of a user can strongly determine his/her perception of ease of use. It may serve as an anchor for early ease of use perceptions. Self-efficacy is defined as a person's belief in his/her capacity to accomplish a task, which is a term closely related to self-perceived knowledge. Similar to the case of self-efficacy, Mullins and Cronan (2021) believe that users regard a system as being easier to use when they have a higher level of self-perceived knowledge. Therefore, in the pretest, self-perceived knowledge is used as a construct for examining older adults' knowledge of mobile payment methods and the following hypotheses are therefore propounded:

H5a-1. Self-perceived knowledge has a positive effect on behavioral intention towards mobile payment usage for older adults.

H5a-2. Self-perceived knowledge has a positive effect on perceived ease of use of mobile payment methods for older adults.

5.2.2 Hypotheses development for pre-test and post-test comparation

Anderson and Dill (2000) indicate that games have a substantial impact on players' thoughts and behavior. Similarly, gamification has also been found to have a positive effect on behavior and attitudes (Landers, 2014; Yang et al., 2017). Gamification is regarded as a goal-oriented system which always embraces reward elements such as levels, points, and badges. As illustrated in expectancy value theory (Eccles & Wigfield, 2020), these goal-oriented elements can lead to changes in beliefs and effort. Hamari and Koivisto (2015) have further corroborated that, if gamification is well-designed, it can foster a sense of

efficiency and an easy-to-use experience of the system, and that it will also leave users feeling more competent with the system. Compared with traditional guidelines or training services, it is evident that gamified methods lead to a more positive attitude, stronger engagement, and more effective knowledge absorption by users (Mullins & Cronan, 2021). Thus, it is suggested that gamification intervention may offer an effective method to help improve users' perceived knowledge and to promote their acceptance of new technology.

With respect to older adults, despite only a limited number of published studies of gamification and technology usage being available, pertinent research in the health domain has generated some useful suggestions about older adults' attitudes towards and perceptions of gamification. A study on gamified physical activity initiatives conducted by Mazeas et al. (2022) found that no significant differences exist between older people and young people regarding the perception of gamification. We therefore suppose that, compared with the pretest, older adults would have an overall improvement in terms of perceived usefulness, perceived ease of use, self-perceived knowledge, and behavioral intention towards mobile payment usage after gamification intervention, and the following hypotheses are accordingly proposed:

H1b. An improvement in the perceived usefulness of mobile payment technology is experienced by older adults following gamification intervention.

H2b. An improvement in the perceived ease of use of mobile payment technology is experienced by older adults following gamification intervention.

H4. An improvement in behavioral intention towards mobile payment technology is experienced by older adults following gamification intervention.

H5b. An improvement in self-perceived knowledge regarding mobile payment technology is experienced by older adults following gamification intervention.

5.2.3 Hypotheses development for post-test

5.2.3.1 TAM constructs

Although perceived usefulness, perceived ease of use, and behavioral intention are expected to change after gamification, it is expected that the relationships between them will be consistent with the original TAM proposition. Previous studies have generated evidence of the effectiveness of the TAM in explaining users' adoption of targeted systems

with gamification. In their study of service marketing, Yang et al. (2017) found that PU and PEOU from the gamification process positively influence customers' brand attitudes. Likewise, Wong et al. (2021) have highlighted the explanatory power of the TAM constructs concerning older adults' behavior following gamification intervention. It is therefore hypothesized that:

H1c. Perceived usefulness has a positive effect on the behavioral intention of older adults towards mobile payment technology after gamification intervention.

H2c. Perceived ease of use has a positive effect on the behavioral intention of older adults towards mobile payment technology after gamification intervention.

H3c. Perceived ease of use has a positive effect on older adults' perceived usefulness of mobile payment technology after gamification intervention.

5.2.3.2 User Knowledge

According to Aggarwal et al. (2015), self-perceived knowledge drives initial decision-making, with the implication that theories related to user intention to adopt technology heavily emphasize self-perceived knowledge. While previous research evaluating the effectiveness of gamification has consistently recognized the significance of learning outcomes, task performance, and knowledge enhancement—typically through assessing pretest-posttest differences—there is a lacuna of analogous studies addressing causal connections pertaining to user knowledge. In this study, with a focus on enhancing both technology adoption and knowledge transfer among older adults, in addition to examining users' intentions, it is critically important to also examine actual users' experiences associated with gamification intervention.

Bhattacherjee and Premkumar (2004) have explained that in the process of gamified learning of mobile payment technology, users' perceptions of their ability tend to be affirmed and, accordingly, users' actual experience and users' intentions may jointly predict their subsequent behaviors. Both self-perceived knowledge (SPK) from a subjective perspective and actual knowledge (AK) from an objective perspective have therefore been used in our research to represent holistic user knowledge. It is further argued that users with a higher self-perceived knowledge and higher actual knowledge are more likely than otherwise to adopt the target technology (Mullins & Cronan, 2021). A strong correlation has been identified between self-perceived knowledge and actual knowledge.

In the context of gamification, Cronan et al. (2012) have reported that a positive correlation prevails between users' perception of knowledge and their actual knowledge. In terms of the relationship between self-perceived knowledge and perceived ease of use, we expect their relation is consistent with the pretest conditions, where users who have higher self-perceived knowledge are more likely to perceive the system as easy to use. As a result, the following three hypotheses are propounded:

H5c-1. User knowledge (self-perceived knowledge & actual knowledge combined) has a positive effect on the behavioral intention of older adults towards mobile payment technology after gamification intervention.

H5c-2. Self-perceived knowledge has a positive effect on the perceived ease of use of mobile payment technology for older adults after gamification intervention.

H5c-3. Self-perceived knowledge has a positive effect on the actual knowledge of mobile payment technology for older adults.

5.2.3.3 Perceived enjoyment (ENJ)

Enjoyment is the primary emotion felt in game playing (Rodrigues et al., 2016). Accordingly, in the gamification literature, hedonic user experiences have always been abstracted as perceived enjoyment (Hamari & Koivisto, 2015) which, in the gamification context, is taken to reflect the extent to which feelings of pleasure and enjoyment are engendered by gamification and the degree to which positive emotional change is generated by the gaming experience. Prior studies have accordingly found that perceived enjoyment positively influences users' evaluations of the embedded game elements and their attitude towards the ultimate goal of gamification (Fitz-Walter et al., 2017; Hamari & Koivisto, 2015; Wong et al., 2021). Enjoyment of the game experience is therefore regarded as the main criterion for measuring the success of gamification (Koivisto & Hamari, 2019). It is therefore postulated that:

H6. Perceived enjoyment of gamification intervention has a positive effect on the perceived effectiveness of gamification.

5.2.3.4 Perceived effectiveness of gamification (GAM)

Although the benefits of gamification for motivating and engaging people have already been highlighted in the literature, the attainment of such benefits in practice is often

undermined by poor game design or lack of methodological rigor (Kalogiannakis et al., 2021). Understanding the relationship between gamification and user behavior therefore requires analysis of gamification itself (Wong et al., 2021).

The perceived effectiveness of gamification (GAM) refers to "the extent to which the gamification facilitates their engagement with the technology that the user precepted and evaluated" (Wong et al., 2021). According to Venkatesh and Speier (2000), gamification aims at enhancing users' intrinsic motivation, on the understanding that when they are intrinsically motivated, they will perceive a higher ease of use. Moreover, gamification has been shown to directly influence user behavior depending on its design and contextual fit (Çera et al., 2020). In other words, effective design and implementation of gamification embedded into a service can result in a better evaluation of learning outcomes and more positive attitude towards technology by users (Hamari & Koivisto, 2013). The following hypotheses are therefore propounded:

H7. Perceived effectiveness of gamification has a positive effect on the perceived ease of use of mobile payment technology by older adults.

H8. Perceived effectiveness of gamification has a positive effect on the behavioral intention of older adults towards mobile payment technology.

H9. Perceived effectiveness of gamification has a positive effect on older adults' user knowledge of mobile payment technology.

5.3 Experimental validation

5.3.1 Participants

The samples were generated using a convenience sampling method. To improve the sample's representativeness of the target population, the data were collected in business areas, restaurants, parks, sports venues, and campuses, distributed across different districts of Hong Kong. The target demographic group of the study was the "young–old" segment of the population, as this group has been shown to have a stronger demand for transactions and higher potential for mobile payment usage.

Although the age groups of 55-75 years or 60-75 years are typically treated as being as "young–old" available statistics indicate that the acceptance rate of AlipayHK drops precipitously as people's age rises above 50 (Hong Kong Productivity Council, 2019). We therefore invited people aged 50-75 to join the study. A total of 122 older adults participated

in the study, with 115 fully completing the tasks and satisfying the requirements, thus generating a 94.26% validity rate. Table 5.1 summarizes the demographic profile of the participants. The sample exhibited a relatively balanced gender ratio (12:11). The largest proportion of the participants were 55-59 years old (34.78%), with most of them (83.48%) having received an education higher than secondary level. The economic status of participants was varied, with the single largest group (39.13%) falling in the middle-income (HKD10,000-HKD29,999) category (Hong Kong Census and Statistics Department, 2021).

Table 5.1 Respondents' demographic profile (n=115)

Variable	Frequency (N)	Percentage (%)
Age		
50-54	26	22.61
55-59	40	34.78
60-64	26	22.61
65-69	14	12.17
70-75	9	7.83
Gender		
Male	60	52.17
Female	55	47.83
Education		
No formal education	1	0.87
Primary	18	15.65
Secondary	44	38.26
Matriculation	10	8.7
Bachelor (or equivalent) and above	42	36.52
Monthly income (HKD)		
Less than 5,000	19	16.52
5,000-9,999	17	14.78
10,000-19,999	32	27.83
20,000-29,000	13	11.30
30,000-39,999	9	7.83
40,000-49,000	7	6.09
50,000 or above	18	15.65

Participants' payment habits and AlipayHK usage experience are summarized in Table 5.2. The majority of the participants (82.61%) considered the Octopus card to be the most common payment method in HK, and only 39.13% used mobile payment services routinely in their daily life. Only 30.43% of the participants had previously used AlipayHK. The most frequently used functions of AlipayHK included scanning QR codes for transactions, topping up account balances, and payment by payment code.

The study included both users and non-users of AlipayHK. As reported by the Hong Kong Productivity Council (2019), despite the presence of older-age (50-64 years old)

users of AlipayHK, many make use of only limited functions and exhibit relatively low user stickiness. There is therefore still a large potential to improve their relevant knowledge and technology adoption. Moreover, comparing both users and non-users enables a more comprehensive understanding of older adults' perceptions.

Table 5.2 Payment habits and AlipayHK usage

Variable	Frequency (N)	Percentage (%)
Commonly used payment method		
Cash	68	59.13
Octopus card	95	82.61
Bank card/credit card	44	38.26
Mobile payment	45	39.13
AlipayHK usage experience		
No usage experience	80	69.57
Have usage experience	35	30.43
Used functions of AlipayHK		
Transaction by scanning QR code	20	17.39
Top-up	16	13.91
Transaction to friends	9	7.83
Taking transportations by EasyGo	8	6.96
Payment by payment code	17	14.78
None	80	69.57

5.3.2 Procedure

This study was reviewed and approved by the Human Subjects Ethics Application Review System (HSEARS) from the Hong Kong Polytechnic University (code: HSEARS20211026010). A pre-experimental, one-group pretest–posttest design was used for this study, where the same measurement was measured in one group of participants prior to and after the intervention (Marsden & Torgerson, 2012). The research process design is shown in Table 5.3.

Table 5.3 One-group pretest–posttest design

O_1	X	O_2
Pretest (Survey of perception and knowledge of AlipayHK)	**Intervention** (Implementation of gamified learning on AlipayHK)	**Posttest** (Survey of perception and knowledge of AlipayHK)

A questionnaire survey method was employed for collecting data. A pilot study of 30 participants was conducted with the aims of: firstly, evaluating the feasibility of gamified learning material; secondly, building superior reliability and validity of the questionnaire; and, thirdly, assessing the survey process. The pilot study consisted of two phases: testing the survey design (Phase 1) and validating it among older adults (Phase 2).

Table 5.4 Demographic profile of the participants in the pilot study

Phase 1		
	Frequency (N)	Percentage (%)
Age		
Under 18	1	11.11
18-29	4	44.44
30-39	1	11.11
40-49	0	0
50-59	3	33.33
Gender		
Male	3	33.33
Female	6	66.67
AlipayHK usage experience		
No usage experience	5	55.56
Have usage experience	4	44.44
Total	9	100.00
Phase 2		
	Frequency (N)	Percentage (%)
Age		
50-54	2	9.52
55-59	7	33.33
60-64	5	23.81
65-69	4	19.05
70-75	3	14.29
Gender		
Male	6	28.57
Female	15	71.43
AlipayHK usage experience		
No usage experience	10	47.62
Have usage experience	11	52.38
Total	21	100.00

Nine volunteers without age limitations were invited for Phase 1, while Phase 2 involved 21 older adults aged between 50 and 75 years. Table 5.4 presents the demographic information of the participants. Based on the feedback received, improvements were made to the gamified material and questionnaire phrasings. It is important to note that this pilot study was independent of the main study, and so, the data from the pilot study were not included in the final study analysis.

In the main study, considering that the survey process was relatively complicated, a face-to-face structured interview procedure was selected instead of a self-administered questionnaire, so as to control data quality. Participants joined the study voluntarily with their informed consent being obtained before commencing the survey (Appendix I and Appendix V). A brief introduction to the study was given to potential participants as part of the invitation. After their acceptance, a pretest survey was conducted, followed by engagement with the gamified learning material, and finally, a posttest survey was performed. The gamified intervention typically took participants 5–10 min, and the surveys (pretest and posttest) took an additional commitment of around 5–10 min. All three phases together thus generally ran for between 10 and 20 min. For participants who aged 70 and above, the MoCA test was conducted before the interview to assess their cognitive ability and ensure the reliability of their responses.

5.3.3 Measurements

The data in the study were divided into four major sets of measurements: (1) payment habits and opinions of AlipayHK (pretest), (2) The AlipayHK game score, (3) Post-game opinions and attitudes (posttest), and (4) demographic information. To ensure the validity of measurement items, all were adapted from widely used scales from prior studies (Appendix VI, and Appendix VI). Both multi-item and single-item measures were adopted. Constructs related to user knowledge, including “self-perceived knowledge” and “actual knowledge,” were measured by a single item. As suggested by Angulo-Brunet et al. (2020), older adults prefer simple presentation and fewer response options, signaling that shortened measures may be an appropriate age-friendly strategy. Diamantopoulos et al. (2012) contend that the single-item measurement approach is optimal if a construct is unidimensional, unambiguous, and concrete. In existing studies, the single-item measurement approach has been widely employed to assess both “self-perceived knowledge” and “actual knowledge” (Aggarwal et al., 2015; Wang, 2017; Buckley and

Doyle, 2017; Kwon and Özpolat, 2021; Chen et al., 2023). Consequently, this approach is considered valid and reliable in the measurement of these constructs.

The two items from user knowledge (self-perceived knowledge and actual knowledge) were anchored on a rating-scale question, ranging from 1 to 10. Except for these two items, all constructs were gauged with a 7-point Likert scale, ranging from 1 (strongly disagree) to 7 (strongly agree). Demographic and payment-habit questions were based on a categorical survey response.

5.4 Results

Data were analyzed using the statistical software, Statistical Package for Social Sciences (IBM SPSS 26), and the Partial Least Squares Structural Equation Modeling (PLS-SEM) tool with SmartPLSv.4.0.9.5. SPSS was used to measure the change between pretest and posttest. PLS-SEM was considered as an appropriate modeling technique to examine the relationship among different constructs as it can provide more predictive accuracy and support for a smaller sample size and requires no distributional assumptions (Roldán & Sánchez-Franco, 2012). Research hypotheses were verified through the two data analysis methods (i.e., pretest and posttest comparison and PLS-SEM) after certifying that the measures were reliable and valid.

5.4.1 Measurement assessment

The validity and reliability of all constructs in the pretest and posttest models were assessed as shown in Table 5.5 and Table 5.6. The results revealed that the construct reliability (CR) for the pretest model ranged from 0.921 to 0.947 and from 0.890 to 0.947 for the posttest model, with both results falling above the recommended level of 0.7. In both cases, Cronbach’s Alpha was also greater than the threshold of 0.7. CR together with Cronbach's Alpha indicated good internal consistency and reliability of the data (Hair et al., 2019). Factor loadings for all items exceeded 0.7, and the average variance extracted (AVE) values were higher than 0.5, thus establishing adequate convergent validity.

Table 5.5 Reliability and validity of the measurement for the pretest model

	Items	Factor loading	Cronbach's Alpha	CR	AVE
Behavioral intention–Pretest (BI–Pre)	BI1–Pre	0.930	0.828	0.921	0.853
	BI2–Pre	0.917			
Perceived Ease of Use–Pretest (PEOU–Pre)	PEOU1–Pre	0.930	0.850	0.930	0.870
	PEOU2–Pre	0.935			
Perceived Usefulness–Pretest (PU–Pre)	PU1–Pre	0.933	0.917	0.947	0.857
	PU2–Pre	0.934			
	PU3–Pre	0.910			
Self-perceived Knowledge–Pretest (SPK–Pre)	SPK–Pre	1.000	1.000	1.000	1.000

Table 5.6 Reliability and validity of the measurement for the posttest model

	Items	Factor loading	Cronbach's Alpha	CR	AVE
Behavioral intention–Posttest (BI–Post)	BI1–Post	0.901	0.752	0.890	0.801
	BI2–Post	0.889			
Perceived Ease of Use–Posttest (PEOU–Post)	PEOU1–Post	0.928	0.850	0.930	0.869
	PEOU2–Post	0.936			
Perceived Usefulness–Posttest (PU–Post)	PU1–Post	0.900	0.895	0.935	0.827
	PU2–Post	0.912			
	PU3–Post	0.915			
Perceived Enjoyment (ENJ)	PE1	0.897	0.893	0.933	0.823
	PE2	0.909			
	PE3	0.916			
Perceived Effectiveness of Gamification (GAM)	PEG1	0.835	0.930	0.947	0.782
	PEG2	0.862			
	PEG3	0.914			
	PEG4	0.922			
	PEG5	0.884			
Self-perceived Knowledge–Posttest (SPK–Post)	SPK–Post	1.000	1.000	1.000	1.000
Actual Knowledge (AK)	AK	1.000	1.000	1.000	1.000

Discriminant validity measures the extent to which a construct differs empirically from other constructs (Hair et al., 2021). In this study the Fornell–Larcker criterion was employed to assess discriminant validity. The results for the pretest constructs (Table 5.7) and the posttest constructs (Table 5.8) both satisfied the discriminant validity requirements.

To determine potential redundancy, the degree of multicollinearity among reflective constructs was examined. All variance inflation factor (VIF) values for the pretest and posttest fell below the recommended threshold of 5 to establish a lack of common method bias (Kock, 2015). Additionally, despite little attention being directed to endogeneity issues in SEM research, Sarstedt et al. (2020) suggest that this is a critical issue when applying regression-based methods such as PLS-SEM to ensure that the model is causally interpreted. The Gaussian copula approach was used to test for endogeneity in the models as the data were non-normally distributed (Table 9) (Hult et al., 2018). The results indicate that endogeneity was not a problem in this study as the significance (P value) of all Gaussian copula terms was higher than 0.05.

Overall, the reliability and validity assessments that were conducted indicated that these two measurement models were appropriate for the next stage, namely structural model analysis.

Table 5.7 Discriminant validity analysis for the pretest model

	BI–Pre	**PEOU–Pre**	**PU–Pre**	**SPK–Pre**
BI–Pre	**0.924**			
PEOU–Pre	0.714	**0.933**		
PU–Pre	0.719	0.743	**0.926**	
SPK–Pre	0.594	0.475	0.384	**1.000**

Notes: Diagonal elements are square roots of average variance extracted (AVE), off-diagonal elements are correlations.

Table 5.8 Discriminant validity analysis for the posttest model

	AK	**BI–Post**	**ENJ**	**GAM**	**PEOU–Post**	**PU–Post**	**SPK–Post**
AK	**1.000**						
BI–Post	0.734	**0.895**					
ENJ	0.660	0.733	**0.907**				
GAM	0.699	0.784	0.816	**0.884**			
PEOU–Post	0.827	0.794	0.753	0.775	**0.932**		
PU–Post	0.649	0.788	0.776	0.802	0.754	**0.909**	
SPK–Post	0.672	0.678	0.555	0.639	0.662	0.649	**1.000**

Notes: Diagonal elements are square roots of average variance extracted (AVE), off-diagonal elements are correlations.

5.4.2 Comparison of Pre-test and Post-test

The normality of data in the pretest and posttest was tested by applying both the Kolmogorov–Smirnov and Shapiro–Wilk tests to data on older adults' perception and attitude change towards AlipayHK before and after the gamification intervention (Razali & Wah, 2011). The results, shown in Table 5.9, indicate that all variables were non-normally distributed (sig. value <0.05). Therefore, the non-parametric Wilcoxon signed rank test was performed to test the statistical change (Woolson, 2007).

Table 5.9 Test of normality

	Kolmogorov–Smirnov[a]			Shapiro–Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Pretest						
Perceived Usefulness						
Full	0.200	115	0.000	0.897	115	0.000
User	0.219	35	0.000	0.875	35	0.001
Non-user	0.178	80	0.000	0.910	80	0.000
Perceived Ease of Use						
Full	0.174	115	0.000	0.892	115	0.000
User	0.218	35	0.000	0.906	35	0.006
Non-user	0.150	80	0.000	0.902	80	0.000
Behavioral Intention						
Full	0.163	115	0.000	0.927	115	0.000
User	0.242	35	0.000	0.910	35	0.007
Non-user	0.145	80	0.000	0.940	80	0.001
Self-perceived Knowledge						
Full	0.226	115	0.000	0.866	115	0.000
User	0.202	35	0.001	0.908	35	0.007
Non-user	0.311	80	0.000	0.802	80	0.000
Posttest						
Perceived Usefulness						
Full	0.223	115	0.000	0.781	115	0.000
User	0.196	35	0.000	0.874	35	0.001
Non-user	0.239	80	0.000	0.777	80	0.000
Perceived Ease of Use						
Full	0.216	115	0.000	0.799	115	0.000
User	0.234	35	0.000	0.769	35	0.000
Non-user	0.213	80	0.000	0.824	80	0.000
Behavioral Intention						
Full	0.244	115	0.000	0.838	115	0.000
User	0.202	35	0.000	0.908	35	0.001
Non-user	0.235	80	0.000	0.860	80	0.000
Self-perceived Knowledge						
Full	0.194	115	0.000	0.856	115	0.000
User	0.277	35	0.000	0.775	35	0.000
Non-user	0.167	80	0.000	0.890	80	0.000

a. Lilliefors Significance Correction

As shown in Table 5.10, the results from the Wilcoxon signed rank test implied that the changes in older adults' perceptions between pretest and posttest were significant with a 95 % confidence interval ($p < 0.05$) in general. In the full-size group, the participants reported significant higher evaluations in the posttest for PU, PEOU, BI, and SPK, with all showing a large effect size (r) using the Rosenthal et al. (1994) criterion of 0.10 - 0.30 (small effect), 0.30 - 0.50 (moderate effect), and > 0.50 (large effect). The results thus supported hypotheses H1b, H2b, H4, and H5b. Compared with the user group, the non-user group presented greater improvements in both pretest and posttest. All measurements in the non-user group indicated a significant change with a large effect size, where the SPK revealed the biggest improvement.

Table 5.10 Wilcoxon signed rank test

Measurement	n	Pretest	Posttest	Z[a]	P	r	Decision
		M (SD)	M (SD)				
Perceived Usefulness							H1b is
Full	115	5.313	5.925	-6.464	0.000	-0.603	supported
		(1.279)	(1.099)				
User	35	5.724	6.200	-3.312	0.001	-0.560	
		(0.972)	(0.729)				
Non-user	80	5.133	5.804	-5.554	0.000	-0.621	
		(1.359)	(1.210)				
Perceived Ease of Use							H2b is
Full	115	5.091	5.939	-6.616	0.000	-0.617	supported
		(1.360)	(1.218)				
User	35	5.643	6.371	-3.352	0.001	-0.567	
		(0.952)	(0.826)				
Non-user	80	4.850	5.750	-5.698	0.000	-0.637	
		(1.444)	(1.314)				
Behavioral Intention							H4 is
Full	115	5.039	6.009	-7.374	0.000	-0.688	supported
		(1.396)	(0.953)				
User	35	5.714	6.314	-3.400	0.001	-0.575	
		(0.987)	(0.557)				
Non-user	80	4.744	5.875	-6.510	0.000	-0.728	
		(1.450)	(1.057)				
Self-perceived Knowledge							H5b is
Full	115	4.660	7.900	-8.696	0.000	-0.811	supported
		(3.142)	(2.218)				
User	35	7.290	8.830	-4.173	0.000	-0.705	
		(2.023)	(1.445)				
Non-user	80	3.510	7.490	-7.536	0.000	-0.817	
		(2.846)	(2.376)				

a. Post-test data-Pre-test data, based on negative ranks.

5.4.3 Structural model assessment

PLS-SEM was used to evaluate the pretest and posttest model. The bootstrapping procedure was performed with 5000 resamples and a percentile bootstrap 95 % confidence interval.

The path coefficients of the pretest model are reported in Table 5.11. The results indicate that PU, PEOU, and SPK before the gamification intervention were positively and significantly related to BI, thus confirming hypotheses H1a, H2a, and H5a-1. PEOU exhibited a significantly positive effect on PU, thus supporting H3a. SPK significantly positively influenced PEOU, supporting H5a-2. These results are consistent with the TAM hypotheses.

Table 5.11 Path coefficients of the pretest model and hypothesis testing

Path	Beta	Standard Deviation (SD)	Percentile 95% Confidence Intervals	T Statistics	P Values	Decision
PU–Pre -> BI–Pre	0.400	0.110	[0.196; 0.622]	3.639	0.000	**H1a is supported**
PEOU–Pre -> BI–Pre	0.268	0.124	[0.013; 0.497]	2.161	0.031	**H2a is supported**
PEOU–Pre -> PU–Pre	0.743	0.056	[0.625; 0.839]	13.353	0.000	**H3a is supported**
SPK–Pre -> BI–Pre	0.314	0.064	[0.187; 0.440]	4.865	0.000	**H5a-1 is supported**
SPK–Pre -> PEOU–Pre	0.475	0.064	[0.343; 0.590]	7.416	0.000	**H5a-2 is supported**

From the path coefficients of the posttest model (Table 5.12), it was found that PU and PEOU after the gamification intervention were significantly positively related to older adults' BI, and the effect on PEOU towards PU was also significantly positively related, thus con- firming hypotheses H1c, H2c, and H3c. These findings were compatible with the pretest results and thus substantiates the TAM. In terms of user knowledge, SPK significantly positively influenced PEOU and AK after gamification intervention, thereby confirming H5c-2 and H5c-3. However, user knowledge, including both SPK and AK, did not exhibit a significant relationship with BI. Hence H5c-1 was not supported. Gamification-related factors were found to be positively and significantly related to technology acceptance factors and user knowledge, in which ENJ exhibited a significant

and positive relationship with GAM, and GAM exhibited a significant and positive relationship with PEOU, BI, and user knowledge. Hypotheses H6, H7, H8, and H9 were therefore supported.

Table 5.12 Path coefficients of the posttest model and hypothesis testing

Path	Beta	Standard Deviation (SD)	Percentile 95% Confidence Intervals	T Statistics	P Values	Decision
PU–Post -> BI–Post	0.284	0.092	[0.115; 0.478]	3.072	0.002	**H1c is supported**
PEOU–Post -> BI–Post	0.225	0.098	[0.030; 0.418]	2.294	0.022	**H2c is supported**
PEOU–Post -> PU–Post	0.754	0.075	[0.560; 0.857]	10.024	0.000	**H3b is supported**
SPK–Post -> BI–Post	0.118	0.085	[-0.060; 0.275]	1.379	0.168	**H5c-1 is not supported**
AK -> BI–Post	0.139	0.088	[-0.041; 0.310]	1.581	0.114	
SPK–Post -> PEOU–Post	0.281	0.074	[0.135; 0.424]	3.805	0.000	**H5c-2 is supported**
SPK–Post -> AK	0.382	0.069	[0.237; 0.507]	5.502	0.000	**H5c-3 is supported**
ENJ -> GAM	0.816	0.052	[0.695; 0.891]	15.673	0.000	**H6 is supported**
GAM-> PEOU–Post	0.775	0.067	[0.606; 0.870]	11.537	0.000	**H7 is supported**
GAM -> BI–Post	0.209	0.090	[0.026; 0.378]	2.313	0.021	**H8 is supported**
GAM -> SPK–Post	0.639	0.064	[0.496; 0.747]	10.050	0.000	**H9 is supported**
GAM -> AK	0.455	0.084	[0.279; 0.613]	5.420	0.000	

To evaluate the quality of the pretest and posttest models, the coefficient of determination (R^2) and the blindfolding-based cross-validated redundancy measure (Q^2) were assessed. As shown in Table 5.13, the pretest model was able to explain 55.2 % of the variance in PU, 22.6 % of the variance in PEOU, and 66.5 % of the variance of BI. The percentage of total variance explained by the posttest model for each endogenous construct was 56.8 % for PU, 60.1 % for PEOU, 66.5 % for GAM, 74.8 % for BI, 40.9 % for SPK, and 57.5 % for AK (Table 5.14). The high R^2 value affirms the in-sample predictive validity of the structural models.

The Q^2 value was also used to examine predictive power. The values of Q^2 for performances in both the pretest model (Table 5.13) and the posttest model (Table 5.14) were larger than zero, indicating a satisfactory predictive accuracy. Moreover, Richter et al. (2016) interpret Q^2 values higher than 0.02, 0.15, and 0.35 respectively as corresponding to small, medium, and large predictive relevance. Based on this criterion, a medium to large predictive relevance is confirmed for the pretest model and posttest model.

Our model—with its explicit consideration of causal connections pertaining to user knowledge, and of the practical impact of users' experiences associated with gamification intervention—possesses superior explanatory power in comparison with gamification models utilized in previous studies (e.g., Wong et al., 2021). Specifically, our model exhibits a higher R^2 Value for BI, indicating a greater explanatory power for behavioral intention and a higher Q^2 for GAM, reflecting stronger predictive capability in assessing the perceived effectiveness of gamification. These findings highlight the enhanced performance and predictive capabilities of our model.

Table 5.13. Results of coefficient of determination (R^2) and predictive relevance (Q^2) of the pretest model

Endogenous Latent Variable	R^2 Value	Q^2 Value
PU–Pre	0.552	0.136
PEOU–Pre	0.226	0.214
BI–Pre	0.665	0.344

Table 5.14. Results of coefficient of determination (R^2) and predictive relevance (Q^2) of the posttest model

Endogenous Latent Variable	R^2 Value	Q^2 Value
PU–Post	0.568	0.486
PEOU–Post	0.601	0.549
BI–Post	0.748	0.506
SPK–Post	0.409	0.305
AK	0.575	0.425
PEG	0.665	0.664

5.5 Discussion

This study has confirmed the effectiveness of the gamification and learning approach in enhancing knowledge transfer and technology adoption for older adults. It has done so from two different angles, namely by employing the Wilcoxon signed rank test for pretest

and posttest comparison and through causal relationship analysis using structural equation modeling (SEM). The study also validated the explanatory power of the proposed structural models, thereby providing insights into our extension of the established technology acceptance model (TAM) and contributing to the development of both gamification research and older adults' research. Figure 5.3 and Figure 5.4 provide a detailed illustration of the final verified models. Fifteen out of sixteen hypotheses were supported. Our findings significantly extend current knowledge by filling the demographic gap in gamification research. Our empirical results highlight the feasibility of gamification as a tool to address the critical issue of the digital divide among older adults.

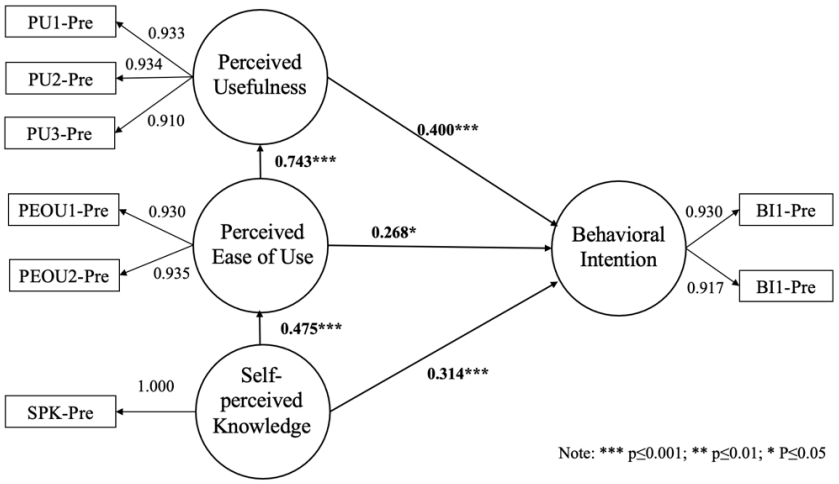

Figure 5.3 The structural model assessment results for pretest

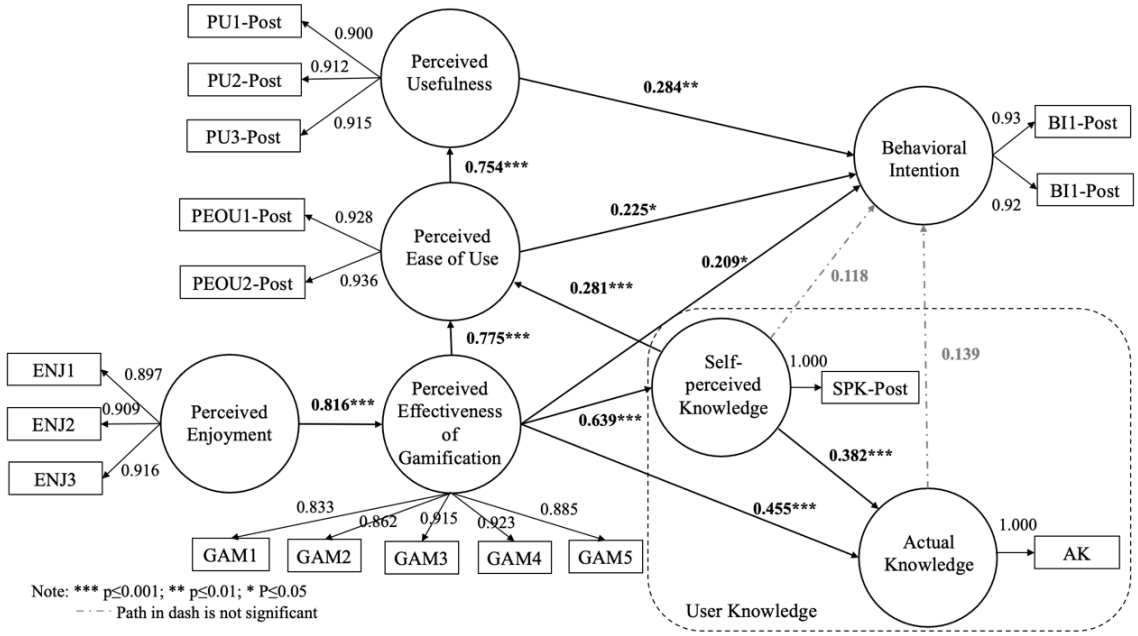

Figure 5.4 The structural model assessment results for posttest

In line with other studies of mobile payment technology (Li et al., 2019b; Thakur, 2013), the findings of our pretest investigation of mobile payment technology adoption by older adults support the idea of the TAM. With respect to user knowledge, a significant and positive influence was found between SPK and BI as well as between SPK and PEOU. The path coefficient of SPK on BI in this study (0.314) is similar in magnitude to the effects of two primary beliefs, PU (0.400) and PEOU (0.268) in the TAM, thereby proving the role of SPK as a critical predictor of older adults' technology adoption and demonstrating the effectiveness of our extension of the TAM. The results are consistent with previous studies reporting that older adults with higher levels of self-efficacy tend to be more likely to perceive technology as easier to use and demonstrate a greater propensity to adopt new technology and vice versa (Mullins & Cronan, 2021; Chung et al., 2010). Additionally, Chen & Chan (2014b) have indicated that a lack of basic skills and knowledge may exacerbate older adults' concerns about using new technology. This may also explain the low adoption rate of mobile payment among participants compared with traditional payment methods in Hong Kong.

After gamification intervention, older adult participants revealed significant enhancements in their PU, PEOU, SPK, and BI towards AlipayHK. These findings substantiated the contention of prior studies that gamification enables improved behavioral and psychological outcomes. Hamari and Koivisto (2015) explained that the ability of gamification to improve performance is associated with its effect on intrinsic motivation, which is the core reason why gamification has been deemed effective. The more that gamification stimulates states of absorption, intense concentration, or stimulation, the more it is perceived as beneficial for the intervention outcomes (Ryan et al., 2006). The notable enhancement in posttest outcomes identified in the study are thus a sign of successful gamification intervention.

In this study, the non-user group experienced a greater positive impact from gamification than the user group. A similar result was found by Marsden and Torgerson (2012) who showed that, when adopting a pretest/posttest research design, interventions are almost always more effective for respondents who have lower scores or performance at the baseline. It is found that non-users tend to have a lower level than users of both understanding AlipayHK and adoption propensity; while this results in a lower overall score than the user group, it also leaves them greater opportunity for improvement. Nevertheless, although non-users show greater pretest to posttest growth, the posttest results reveal that users overall have higher SPK and a stronger tendency to use AlipayHK

than non-users. There are nevertheless several exceptions to the general rule. We found that some participants either believed that AlipayHK was more difficult to use, or gave a lower rating for SPK, after gamification intervention.

In follow-up interviews that were administered to these participants, they indicated that AlipayHK is more functional and has a more sophisticated system than they expected and therefore that, after acquiring a better understanding through gamification intervention, they instead perceived a lower level of ease of use and self-owned knowledge. The Dunning–Kruger effect, which argues that individuals who lack knowledge or have less capability are more likely to over-assess their abilities in some contexts (Kruger & Dunning, 2002), may help explain this phenomenon.

The pre and post outcome assessment approach we adopted is typically employed in learning and education research, with some researchers regarding it as a key approach to ascertaining the effectiveness of teaching games and gamified learning (Buckley & Doyle, 2016; Fernandez-Rio et al., 2020). According to Dyer (2015), the pre/post approach incorporates a constructivist perspective to demonstrate how participants will learn effectively and integrate this process with gamification design and measurement through prior and new knowledge. In addition to knowledge transfer, the present study also confirmed the validity of pre/post assessment in terms of technology adoption, by extending the application scope of pre/post assessment, and it provides a promising measurement methodology for gamification in other fields.

Importantly, this study examined the relationship between gamification with technology usage intention and that with user knowledge, thereby providing insights about "how" gamification may improve technology adoption and knowledge transfer. In the posttest model, the results suggest a strong positive association between ENJ and GAM. As suggested by most gamification studies, GAM plays a role in accelerating and motivating an individual's knowledge absorption and technology adoption, through generating a sense of enjoyment and playfulness that may subsequently improve the motivation of individuals to achieve utilitarian goals (Eppmann et al., 2018). With a Beta value of 0.209, GAM results in our study exhibited a similar determining power to that of PU (0.284) and PEOU (0.225) on BI. Our results echo prior studies but extend existing knowledge of gamification from a demographic perspective. Notwithstanding the mixed results of previous gamification trials among older adults (Koivisto & Malik, 2020), by focusing on older adults, and by using a sophisticated research design, our study has generated empirical evidence for the effectiveness of gamification beyond the young

generation, and we have confirmed the claim that older adults may also enjoy and engage in game elements (De Schutter, 2011).

Besides its effect on technology behavioral intention, a particularly strong effect was also found between GAM and PEOU. This finding is in line with prior studies showing that people's enjoyment of gamification experience enables them to be aware of the ease of use of new technology (Wang & Scheepers, 2012). Although we did not hypothesize it, we thus observed that PEOU plays a mediating role between GAM with BI and that with PU. This suggests that although GAM is regarded as a key influence on older adults' technology adoption intention, it may also be efficiently harnessed for building the evaluation of technology adoption behavior by improving PEOU. Moreover, an indirect effect between GAM and PU can also in turn contribute to BI. This study has therefore generated evidence that gamification facilitates older adults' technology involvement not only in regard to their ultimate adoption intention but also their perception of the required effort and utility of the technology.

Notwithstanding that the posttest results demonstrated a strong positive relationship between gamification and user knowledge (UK), contrary to both the hypothesis and pretest results, the association between BI and UK—although positive—was not significant. Regardless of the statistical significance of the effect between UK and BI that has been found in the majority of studies (Kumar et al., 2020; Makki et al., 2016), some have reported non-significant relationships (Johnson & Ogletree, 2017). The results of our pretest and posttest comparison, and of previous studies, provide evidence that gamification intervention has the potential to change individuals' perceptions and behavior, and may explain the altered posttest effect, in accordance with the conclusions of other studies. One such study (Davis et al., 1989) indicated that PEOU had a significant effect on BI in relation to the system when it was just introduced to users, while the effect became statistically non-significant 14 weeks later.

Nevertheless, SPK demonstrates a particularly strong direct effect on PEOU, which establishes an indirect effect between SPK and BI. This echoes the argument that the level of task complexity plays a significant role in influencing the strength of the relationship between self-efficacy and performance (Igbaria & Iivari, 1995; Mullins & Cronan, 2021). Additionally, participants' SPK presents a significant positive effect with AK, consistent with the observed relationship between self-perceived and actual knowledge in other contexts. The extant literature thus justified our decision to integrate user knowledge into the established Technology Acceptance Model (TAM) and to investigate the role of user

knowledge as a factor influencing the behavioral intentions of users.

However, based on our intriguing empirical results, in which the positive relationship between user knowledge and behavioral intention was found to be statistically insignificant, we adjusted our model accordingly as depicted in Figure 5.5 and 5.6, by eliminating their direct connection.

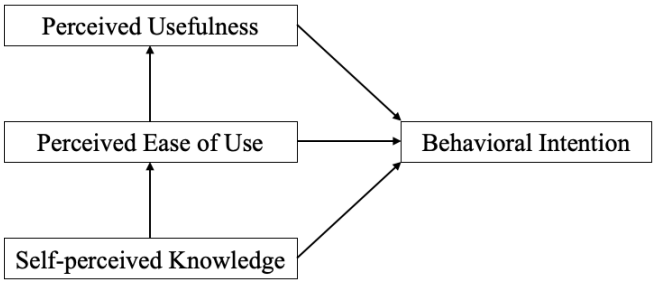

Figure 5.5 Adjusted structural model for pretest

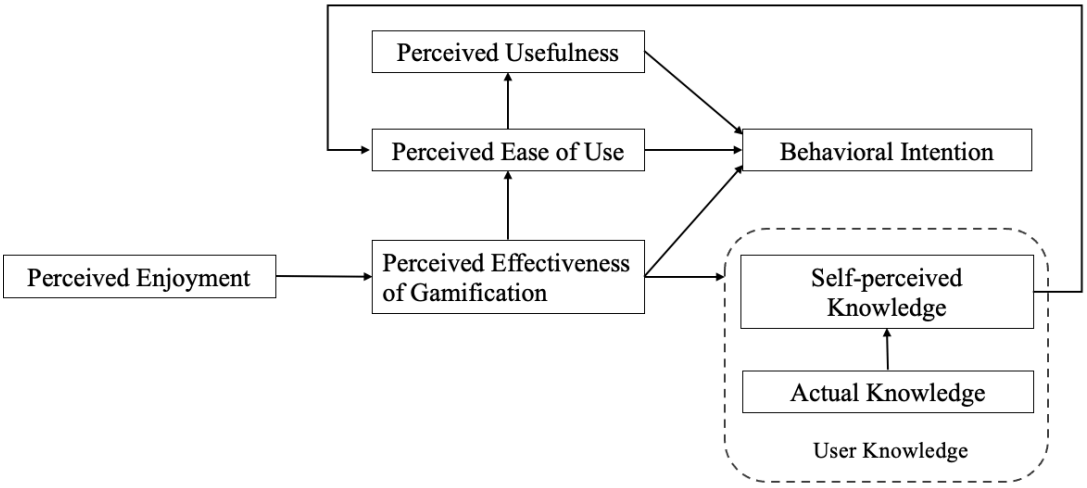

Figure 5.6 Adjusted structural model for posttest

Finally, a few observations from the data collection process deserve discussion. Firstly, although the effectiveness of gamification in improving older adults' technology knowledge and adoption has been confirmed in this study, there are some exceptions. In the total of 122 participants, 7 failed to complete the survey, the main reason being their low education level (i.e., no formal education) and a strong intrinsic resistance to using mobile payment technology. Secondly, the interface and operation of AlipayHK in the gamified learning material was simulated the real AlipayHK platform, and during the survey, participants complained about aspects of the AlipayHK interface design, such as the small text size, small button, and insufficient space. This finding is in line with the problem addressed in the literature review that the age-friendly adaption of mobile

technology is not common (Knowles et al., 2019). In fact, age-friendly adaption has already been launched in the mainland China version of the Alipay app, with a larger button, larger text size, and simpler layout, while not yet integrated into AlipayHK. Although there is evidence that gamification can improve older adults' behavioral intentions towards technology adoption, low levels of age-friendliness in the software app interface may reduce their usage experience, which in turn may influence their willingness to continue use (Iancu & Iancu, 2020). It is therefore recommended that a motivational service strategy such as gamification be accompanied by an age-friendly design to achieve better advances in the use of technology for older adults.

5.6 Summary

This chapter presented the examination of gamification performance on knowledge transfer and technology adoption via an empirical study employing two analytical approaches: the Wilcoxon signed rank test and PLS-SEM. The results demonstrated the effectiveness of gamification for older adults, thereby contributing to research in the gamification field by filling the demographic gap and challenging the stereotypical view that games only serve young people. At the same time, this study offers a promising and turns key solution to the burning issue of the digital divide among older adults.

5.6.1 Implications

This study makes a pioneering contribution to nascent research exploring the potential of gamification for enhancing older adults' technology usage. Through a comprehensive approach that encompasses design, development, and empirical validation, we contribute to the advancement of knowledge transfer in this emerging field and provide practical insights for the design of gamification for older adults.

5.6.1.1 Theoretical implications

Firstly, from a theoretical perspective, the inclusion of gamification in older adults' technology adoption research represents a novel contribution to the field by confirming the generalizability of gamification for varied users' profiles and by adding a new dimension for research on facilitating older adults' technology acceptance and adoption. By integrating gamification principles into the technology adoption process for older adults,

this study breaks new ground in understanding how game elements can enhance their knowledge transfer and overall acceptance of technology.

Secondly, this design framework integrates older-adult-centered design, technology knowledge transfer, and gamification design concepts. This approach surpasses other gamification design frameworks in two primary ways. First, it is grounded in theory, setting it apart from the majority of previous studies that lack of theoretical foundation. Even among those that do employ theory tend to focus on widely popularized theories such as self-determination theory and flow theory, without adequately considering the unique contextual factors at play (Huang & Hew, 2018). Second, close examination of the literature on gamification studies reveals that no theory-based design framework for older adults has previously been developed. The positive results in this study challenge the prevailing inconclusive or pessimistic findings in the gamification literature for older adults. Our approach thus addresses the existing gap in the literature and provides a valuable contribution to the field of gamification research, particularly in the context of older adults. This study provides evidence that by incorporating tailored affordances and employing a theory-based design process, it is possible to create a more engaging and effective gamified experience.

Thirdly, the results of this study offer an exciting approach to understanding the adoption of technology through a technology acceptance model extension by adding two new types of constructs: gamification-related constructs and user-knowledge-related constructs. We demonstrated how gamification-related constructs contribute to explaining the adoption of technology among older adults, and thus provide a valuable framework for future studies to evaluate the value of gamification in driving technology acceptance and adoption. While a number of studies have acknowledged the influence of user knowledge on technology usage, we have made a pioneering contribution here by integrating these constructs within the TAM. This extended Technology Acceptance Model could not only be applied to older adults' technology adoption but also extended to other scenarios, such as student learning and staff training performance.

This study reveals the indirect effect of self-perceived knowledge on behavioral intention, while the direct effect of user knowledge on older adults' behavioral intention is inconclusive. Regardless of the significance of the relationships associated with user knowledge, this study makes valuable contributions to the field and TAM by advancing theoretical knowledge. By exploring the distinctive dynamics of user knowledge within the gamification context, our findings challenge and extend the existing understanding,

and pave the way for furthermore nuanced investigations of the relationships between key factors in the model.

Furthermore, the study demonstrated the effectiveness of employing the pretest and posttest research method, which is commonly used in gamification studies for learning and education but rarely applied in other contexts. Moreover, unlike most pretest and posttest studies that analyze the results mainly by comparing the pretest and posttest change, the relationships between different variables are also explored, thus offering a new paradigm on data analysis for pretest and posttest studies.

5.6.1.2 Practical implications

This study also has significant practical implications, particularly in addressing the pressing challenges of bridging the digital divide among older adults. One of the most notable contributions of this study is the provision of a useful means to help older adults to more easily embrace technology-related products and services. The validated tailored gamification design framework for older adults offers an effective approach that practitioners may employ when designing and developing gamification strategies.

In this design and development process, some lessons have been learnt and summarized which could be helpful in future designs. This study challenges the contention that gamification is less applicable to older adults and addresses the importance of designing games that are fit for older adults. For instance, we discovered that lack of confidence is a key factor inhibiting older adults' game play, and therefore that positive feedback may help to enhance older adults' enjoyment of gamification. Moreover, older-adult-centered design should concern not just gamification, but age-friendly design concepts should be considered for the whole system design to achieve a better gamification effect. *It is therefore recommended that it should not be seen simply as a matter of adding game elements into a non-game system for gamification design to succeed, but rather as a challenge of ensuring that the context-fit, the user-fit, and the system-fit all play a critical role.*

Secondly, this study demonstrates a systematic process for developing and evaluating theory-driven gamification designs. It outlines how to build the theoretical foundation for the gamification design context, systematically apply a gamification design model in practice, and assess the effectiveness of the developed system. By providing a stepwise approach to applying the gamification design model in the real world, it equips

practitioners with a practical framework for effectively incorporating gamification. Since gamification has rarely been applied in research related to older adults, it is currently difficult for technology providers and game-design practitioners to find guidance in the literature about how to gamify service activities. Our guidance streamlines the design process and enhances the potential for success. Furthermore, it also provides a paradigm for the development of customized approaches with a theoretical underpinning applicable in different scenarios, in contrast to generic models or frameworks. AlipayHK serves as a case study to illustrate how a tailored, theory-driven gamification system can be designed, developed, implemented, and evaluated. This research framework can be applied to diverse scenarios for creating user-centered and context-appropriate gamification systems. For example, when developing gamified learning materials for students, the framework can be adapted to integrate learner characteristics, instructional design theory, and gamification principles. Researchers can then employ the proposed extended Technology Acceptance Model to assess the effectiveness of the gamified system. This systematic approach ensures robust and empirically validated outcomes.

Finally, this study highlights the importance of incorporating practical insights into the design process. During the design and development of our gamification system we placed great importance on integrating older adults' specific needs and on factoring in practicality. From the results, the original AlipayHK interface design has been subjected to criticism by older adults due to its lack of age-friendly features, and the instructions provided on its official website also present accessibility challenges for this demographic. Recognizing these problems, our gamification system has been meticulously developed with a distinct emphasis on addressing the unique needs of older adults and integrating practical considerations, thus enhancing their overall experience and acceptance. Cheng et al. (2022) found that many older-adult-related products often encounter difficulties in overcoming the "valley of death," primarily attributable to the scarcity of practical insights into the design and development process. This study as a result advocates the utilization of practical insights in design, development, and delivery of technology to foster a more inclusive and user-friendly experience.

5.6.2 Limitations and way forward

This study has several limitations that invite further investigation. Firstly, we used a single case to evaluate our gamification approach. Repetition of the desired outcome is a

key to success (Robson et al., 2015), and so additional studies of other technologies are needed to justify drawing more general conclusions.

Secondly, while all the determinants that we investigated in this study were found to contribute positively to the use of mobile payment systems by older adults, it would be appropriate for additional barriers to the adoption of emerging technology—such as perceived risk and self-anxiety—to be systematically studied in future research. This study was an initial investigation of the effectiveness of gamification for older adults, but it may pave the way for future research identifying the obstacles to technology adoption by target groups and possible pathways for such obstacles to be overcome.

Thirdly, this framework cohesively and holistically integrates gamification, learning approach, and older-adult-design, drawing conclusions based on the observed impact of this total solution. We conducted a pretest and posttest comparison to investigate the effectiveness of our gamification approach, while lacking a direct comparison with non-gamification learning or training. Further studies ought therefore to explore causality and differentiate the specific effects of gamification. The gamification effectiveness will also be compared across different demographic groups.

Chapter 6 Conclusions and Suggestions for Further Work

6.1 Thesis summary

With the confluence of technology advancement and the progressively aging society, prior studies have acknowledged a large area of advantages of gerontechnology for older adults, such as the benefits in relation to social and self-understanding, interaction benefits, and benefits with task-oriented goals. The digital divide among older people leads them to become more disenfranchised from and disadvantaged by technology. To cope with older adults' low technology acceptance and adoption issue, this study aimed to develop a gamified approach and system for the servitization of gerontechnology in order to facilitate older adults' use of technology.

We performed the whole research by abductive reasoning. Firstly, the research was conducted to understand older adults' gerontechnology acceptance. A roadmapping method was used to provide an overview and vision of a gerontechnology product service system for older adults. It forecast a promising future trend of ICT-oriented gerontechnology for older adults and highlighted the challenges in its development. Subsequently, a quantitative study with a purposely designed survey was conducted to investigate the factors influencing older adults' adoption and use of gerontechnology and enhance the understanding of how to better design and deliver gerontechnology services. The findings underscore the pitfalls of inadequate supportive services for gerontechnology, especially the provision of tutor services during initial use. Moreover, it underscores the value of holistic design approaches that seamlessly integrate products and services into a cohesive system tailored to enable and encourage technology adoption among older adult users. As a whole, the results provide a comprehensive view of the current status, progress, and challenges in older adults' gerontechnology usage, which lays down the fundamental development of the gamification approach in this study.

Gamification as a servitization strategy has been proposed as a promising methodology for improving older adults' technology adoption. The iterative research was followed up to guide the gamification system design, development, and implementation. Considering aging-specific characteristics, a theory-driven design framework was established to integrate gamification design, technology knowledge transfer, and older adults centered design concepts together. Most existing gamification design frameworks

focus on young people or set the default target audience as young people. Our framework avoids the possible unsatisfactory outcome caused by unreflective applications of design frameworks in older adult studies.

An experimental study was then conducted to evaluate the performance of the proposed framework. The results reveal notable improvements in the knowledge and technology adoption intention of older adults with gamification intervention and significantly positive relationships between gamification effectiveness and technology adoption constructs. This validates the effect of gamification on older adults and generates implications for gamification application in the silver-hair market, which indicates the advancement of gamification as a solution for older adults' technology adoption enhancement.

6.2 Contributions

The aging of the population imposes an ongoing and significant challenge for contemporary society, and this thesis presents a concrete solution to alleviate the pressures associated with an aging population. The potential of technology to enhance the quality of life and promote independent living among older adults is widely acknowledged. However, older adults have lagged behind in terms of accepting and adopting technology. Several researchers have made efforts to explore the underlying reasons for the low technology adoption rates among older adults and have focused on designing products specifically for this demographic. Nonetheless, there has been insufficient investigation into how to facilitate older adults' use of existing technology and promote the diffusion of new technological products. This thesis stands out as one of the few scholarly works that addresses this particular issue, making noteworthy contributions from both theoretical and practical perspectives.

6.2.1 Theoretical contributions

This research introduced a different way to understand older adults' technology adoption from the literature. In addition to studying the existing knowledge from prior research, this thesis is one of the first to develop a roadmap for gerontechnology development. As contended by Lee (2022) and Smith (2019), the evolving demographics together with the changing environments and evaluation in technology are altering older adults' technology usage behavior; therefore, using stereotypes and previous assumptions

are inappropriate. The roadmapping methodology offers a way to not only review the past, building on the present, and forecasting the future of gerontechnology development, but also explore the linkage of the factors influencing its progress within the timescale.

It allows researchers to truly understand users and enables designers, developers, and marketers to fully engage with the breadth and dynamics of the factors that drive older adults' adoption and use of technology. The author appeals that this methodology and the roadmap structure constructed in this thesis can be applied in future research on older adults' technology access so as to more precisely capture the needs of older adults and the development of technology, and then match them in a better way.

Secondly, it is one of the few addressing the service aspect of technology for older adults, thereby filling the research gap in this area. It reveals the current shortage of research on gerontechnology servitization in academia and the neglect of service design, development, and delivery in industry. Rather than studying service as a sole subject, this research considered products and services as a whole for providing a total solution for older adults. It identified different levels and types of services that can be applied for older adults in Chapter 3 and demonstrated how services may add value to products in Chapter 4 and Chapter 5. The findings and research process provide references for this domain.

Thirdly, the gamification design framework for older adults extended the research scope of gamification from the demographic perspective and confirmed the generalizability of gamification in terms of varied users' profiles. Simultaneously, it also added a new dimension for research on enhancing older adults' technology acceptance and adoption. Recognizing the differences between younger people and older adults, although several studies have been conducted to investigate the gamification for older adults, there was no older adults specified design framework before this research. The framework proposed in this thesis is grounded in theory from gamification, technology acceptance, and older adult research areas. It not only contributes a design model to the field, but these theories can also be used in the future exploration of gamification use in older adults.

Fourthly, the research methodology presented in this thesis is triangulated and theory guided, which increases the reliability of the research outcome. This research follows a problem-solving logic. As a result, it basically adopted a sequential design. While the relationship among the three phases is not linear but iterative, the later phase is built on the outcome of the former, and the findings of the latter could help to validate and modify the former phase. In this way, this research forms a methodological triangulation. The data and evidence were gathered and analyzed using various methods, instead of a single source of

data. Literature review, roadmapping, and a user survey were used to identify the problem, and a case study via one group pre-post testing was adopted to examine the effectiveness of the research approach.

Moreover, this study is grounded in a robust theoretical framework that is widely applicable across different contexts. The research design and methodology are sound and based on universally recognized principles. As a result, the findings possess strong generalizability and can be applied to other cultural settings to investigate older adults' technology usage and facilitate their technology adoption. Furthermore, the research design concept and framework are adaptable to different populations and contexts. For example, the gamification design framework and the extended technology acceptance model can be tailored to study students' learning outcomes or employees' training performance.

6.2.2 Pragmatic implications

The intention of this research was to provide a turnkey solution for enhancing older adults' technology adoption; therefore, the most direct contribution of this thesis in practice is the gamification design framework for older adults, which can be used by gerontechnology developers and service providers for designing and developing gamification strategies. Narrowing down into the context of the case study of mobile payment promotion in Hong Kong, the gamification approach for AlipayHK developed in this research has evidenced its effectiveness in improving older adults' interest and adoption of this technology. If there is an opportunity to publicize this material, it may help governments and vendors to boost the penetration of mobile payment among older people. Moreover, policy and practical implications in this research are not limited to Hong Kong. Population aging and low technology adoption among older adults are global challenges. The findings of this study suggest ways to enhance technology acceptance among older adults and contribute to the global discourse on leveraging technology to support aging in place, particularly in regions that are experiencing similar demographic shifts.

It also provides inspirations to gamification research in other scenarios. Gamification is not a one-size-fits-all methodology that can be applied to all situations; each situation is unique and should be tailored to the context, the task, the system, and the target users. This research demonstrates a process by which theory-driven gamification design can be systematically developed and evaluated, including how to select a motivational theory that

is appropriate for the gamification design context, how a gamification design model can be step-by-step applied in practice, and how to assess the effectiveness of developed systems. It encourages more customized approaches with theoretical underpinning applied in different scenarios, rather than a generalized model or framework, which is more promising to generate satisfactory results.

Furthermore, this research may raise the awareness of the services for gerontechnology among all the related stakeholders, including but not limited to technology providers, business managers, salespersons, government, non-profit organizations, and caregivers. In the population aging society, stakeholders should acknowledge the benefit from technology and opportunities in the silver-hair market. The results of this thesis provide them with important knowledge on how to integrate services into products to allow better technology access for older adults.

6.3 Suggestions for further work

Services, as much as products, are a critical part of gerontechnology. This thesis evidences the importance as well as the deficiency of servitization in gerontechnology development. Although servitization has been addressed in this thesis through a comprehensive study and gamification as one of the promising servitization strategies is proposed for improving older adults' technology adoption from a motivation enhancing perspective, there are still major gaps in academic research and industry application of servitization. The results in this research also inspire alternative servitization approaches and directions beyond gamification for further investigation. One possible research area is the customization of services for older adults. Older adults are a heterogeneous group with a broader variety of socioeconomic status, education level, and physiological conditions than that of the younger generation (González et al., 2012). The findings in Chapter 3 suggest that differences in both technology features and the characteristics of older adults influence their perceptions and needs in relation to technology. Services that are tailored to older adults' specific demands and preferences may be more effective in promoting their adoption of technology. Research could explore how service customization can be achieved in practice, and how it can be used to improve the user experience for older adults. Additionally, with the popularity of AI, lots of activities incorporate AI to enhance efficiency, foster innovation, and deliver tailored experiences. Consequently, it is worth to exploring the role of AI technologies as a servitization strategy in improving older adults'

technology acceptance. Large language models (LLMs), such as DeepSeek, ChatGPT, or other advanced AI systems, can generate personalized tutorials and on-demand help to assist older adults' technology adoption. Moreover, LLMs can offer data-driven, tailored experiences that align with individual preferences and abilities. Nevertheless, AI itself represents an advanced technology, which poses significant barriers for older adults' acceptance and adoption. As a result, how to encourage older adults to accept AI-driven services and how to leverage AI to facilitate their technology adoption are both important topics for further investigation.

Secondly, this study selects Hong Kong as a case study to investigate older adults' technology usage and examine the effectiveness of gamification. It provides a foundation for further research in different cultural contexts. Given the variations in cultural norms, lifestyles, and social structures across regions, future research should incorporate cross-cultural comparisons to identify the similarities and differences shaped by cultural and regional factors. By doing so, it can strengthen the generalizability and broader applicability of the research findings. Besides, longitudinal study can be done to track changes in older adults' technology acceptance and adoption and identify trends in technological products and services development.

Moreover, gamification is an innovative approach for older adults, especially in technology adoption. This thesis examined the feasibility and advantages of gamification through empirical evidence, whereas a single case is not able to draw a comprehensive conclusion. More cases on gamification for promoting older adults' technology acceptance and adoption are needed. While the gamified technology knowledge transfer approach introduced in this research mainly serves the initial stage of technology usage, gamification can also be applied during older adults' technology usage to increase customer retention or to engage older adults prior to their adoption of a technology. In addition, for different types of technology, gamification strategies may yield different effects. As a result, further case studies are warranted to help us optimize our current model and dig deeper into the implications of gamification for older adults' technology adoption.

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Appendices

Appendix I

CONSENT TO PARTICIPATE IN RESEARCH

A GAMIFICATION APPROACH FOR ENHANCING OLDER ADULTS' TECHNOLOGY ADOPTION AND KNOWLEDGE TRANSFTER OF GERONTECHNOLOGY FOR AGING IN PLACE

I _____ hereby consent to participate in the captioned research conducted by ___CHEUNG Chi Fai_____.

I understand that information obtained from this research may be used in future research and published. However, my right to privacy will be retained, i.e., my personal details will not be revealed.

The procedure as set out in the attached information sheet has been fully explained. I understand the benefit and risks involved. My participation in the project is voluntary.

I acknowledge that I have the right to question any part of the procedure and can withdraw at any time without penalty of any kind.

Name of participant _____

Signature of participant _____

Name of Parent or Guardian (if applicable) _____

Signature of Parent or Guardian (if applicable) _____

Name of researcher _____CHEUNG Chi Fai_____

Signature of researcher _____

Date _____

Hung Hom Kowloon Hong Kong 香港 九龍 紅磡
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Appendix II

THE HONG KONG POLYTECHNIC UNIVERSITY
香港理工大學

INFORMATION SHEET

A STUDY ON SERVITIZATION OF GERONTECHNOLOGY FOR AGING IN PLACE

You are invited to participate in the above project conducted by AN Siyang, who is a PhD student of the Department of Industrial and Systems Engineering in The Hong Kong Polytechnic University. The project has been approved by the PolyU Institutional Review Board (PolyU IRB) (or its Delegate) (Reference Number: HSEARS20211026010).

The aims of this project are enhancing older adults' gerontechnology acceptance through servitization process and assist manufacturers increase their understanding and satisfaction on old adults and improve their competitiveness. You are invited to complete a questionnaire, which will take you about 20 minutes.

The information you provide as part of the project is the research data. Any research data from which you can be identified is known as personal data. Personal data does not include data where the identity has been removed (anonymous data). We will minimize our use of personal data in the study as much as possible. The researcher and her team, supervisor, collaborator (including Prof. CHEUNG Chi Fai, AN Siyang, CHENG Mei Na, LO Yu Ting, HAU Ho Hin within Hong Kong and Prof. Kelvin Willoughby outside Hong Kong) will have access to personal data and research data for the purposes of the study. Responsible members of The Hong Kong Polytechnic University may be given access for monitoring and/or audit of the research.

All information related to you will remain confidential and (please provide information on how information will be kept and accessed, e.g., will be identifiable by codes only known to the researchers). The information collected will be kept until (please provide an expiry date or a reference to a milestone, like 2 years after project completion/publication or public release of research results). The Hong Kong Polytechnic University takes reasonable precautions to prevent the loss, misappropriation, unauthorized access or destruction of the information you provide.

You have every right to withdraw from the study before or during the measurement without penalty of any kind.

If you have any questions, you may ask our helpers now or later, even after the study has started. You may contact Prof. CHEUNG Chi Fai (tel. no.: +852 27667905/ email: benny.cheung@) or AN Siyang (tel. no. +852 5229 /email: siyang.an@) of PolyU under the following situations:

a. if you have any other questions in relation to the study;
b. if, under very rare conditions, you become injured as a result of your participation in the study; or

c. if you want to get access to/or change your personal data before (the expiry date).

In the event you have any complaints about the conduct of this research study, you may contact Secretary, PolyU Institutional Review Board in writing (institutional.review.board@polyu.edu.hk) stating clearly the responsible person and department of this study as well as the Reference Number.

Thank you for your interest in participating in this study.

Prof. CHEUNG Chi Fai
Principal Investigator/Chief Investigator

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Appendix III

Questionnaire for gerontechnology product-service system

Hello! We are students of the Department of Industrial and Systems Engineering of the Hong Kong Polytechnic University. We are conducting a questionnaire survey. Could we take about 20 minutes of your time to answer some questions about your views and expectations on technology products? The research results may help to improve products and services design in the future and therefore better fulfill the needs for older adults. All collected information will be kept confidential and will only be used for the analysis of this research. Thank you.

(A). Demographic information

1. Age	
2. Gender	□Male □Female
3. Nationality	
4. Where are you living ?	□Living with family members or relatives □Living alone □Nursing home
5. Which types house are you living?	□Private housing □Home Ownership Scheme (HOS) □Public housing □Village housing □Others_____
6. What's your house holding status?	□Owned □Mortgage □Rent
7. What's your education level?	□No formal education □Primary school □Secondary school □High school □Pre-college □College degree or above
8. What's your marital status?	□Married □Divorced □Widowed □Separated □Unmarried □Cohabited
9. What's your working status?	□Full-time job □Part-time job □Retired □Self-employed

(B). Technology knowledge and experience

The list below demonstrates varied technology product, please point out your experience with each product.

From 1 to 5: (1) Never heard; (2) Heard but never use; (3) used at least once; (4) Occasionally use; (5) Usually use

Technology product	Score				
1. Voice communication (e.g., Skype, face time)	1	2	3	4	5
2. Social media (e.g., Facebook, WeChat, Instagram)	1	2	3	4	5
3. Personal emergency alert（e.g., Pressed emergency alarm）	1	2	3	4	5
4. Electronic cooking (e.g., induction cooker)	1	2	3	4	5
5. Smart home control system	1	2	3	4	5
6. Sensory enhancement assistive device	1	2	3	4	5
7. GPS (e.g., car navigation system， Google map)	1	2	3	4	5
8. Medication reminder (MedCoach (app in iPhone))	1	2	3	4	5
9. Telikin Computer	1	2	3	4	5
10. Heath tracking devices (storing and organizing health data, such as blood pressure and heartbeat)	1	2	3	4	5
11. Computer	1	2	3	4	5
12. Recreation apps	1	2	3	4	5
13. Education assistance program (e.g., electronic dictionary)	1	2	3	4	5
14. Mobility aids device (e.g., electric wheelchair, electric stick)	1	2	3	4	5
15. Automated machine (e.g., ATM, self-service kiosks)	1	2	3	4	5
16. Credit card	1	2	3	4	5
17. Smartphone	1	2	3	4	5
18. Smart bus card（Octopus card）	1	2	3	4	5
19. Healthy/massage/sport equipment (e.g., running tracker)	1	2	3	4	5
20. Digital camera	1	2	3	4	5
21. CD/MP3/MP4 /DVD/VCD	1	2	3	4	5
22. EPS, PayPal	1	2	3	4	5
23. Other: _____	1	2	3	4	5

(C).Technology adoption factor

Please choose two technology products among the list above, one is the 'easiest-to-use' product, another is the 'hardest-to-use' product.

The 'easiest-to-use' product: _____

The 'hardest-to-use' product: _____

Reasons for thinking it is 'easy-to-use'	Strongly disagree	Disagree	Neutral	Agree	Strongly agree	Not applicable
Be able to afford	1	2	3	4	5	N/A
Have technical support (from manufacturer)	1	2	3	4	5	N/A
Have social support (from family and friends)	1	2	3	4	5	N/A
Emotional enjoyment	1	2	3	4	5	N/A
Be able to use independently	1	2	3	4	5	N/A
Have confidence to use	1	2	3	4	5	N/A
Reliable system	1	2	3	4	5	N/A
Trust with services	1	2	3	4	5	N/A
Compatible with other products	1	2	3	4	5	N/A
Personal lifestyle fit	1	2	3	4	5	N/A
Product information sharing	1	2	3	4	5	N/A

Reasons for thinking it is 'hard-to-use'	Strongly disagree	Disagree	Neutral	Agree	Strongly agree	Not applicable
Be unable to afford	1	2	3	4	5	N/A
Don't have technical support (from manufacturer)	1	2	3	4	5	N/A
Don't have social support (from family and friends)	1	2	3	4	5	N/A
Emotional aversion	1	2	3	4	5	N/A
Be unable to use independently	1	2	3	4	5	N/A
Don't have confidence to use	1	2	3	4	5	N/A
Unreliable system	1	2	3	4	5	N/A
Not trust with services	1	2	3	4	5	N/A
Incompatible with other product	1	2	3	4	5	N/A
Personal lifestyle unfit	1	2	3	4	5	N/A
Without product information sharing	1	2	3	4	5	N/A

(D).People's opinion on product-service system

Nowadays, many manufacturers not only sell technology product, but also provide after-sale service or other related services for their product, such as providing instruction book, training tutorials, customer service hotline etc.

Next, please based on the 'easy to use' and the 'hard to use' product you choose to express your opinion on following questions.

'easy to use' product	'hard to use' product
1. I don't need anyone to teach me how to use the product □Strongly disagree □Disagree □Neutral □Agree □Strongly agree	1. I don't need anyone to teach me how to use the product □Strongly disagree □Disagree □Neutral □Agree □Strongly agree
2. I feel unpleasant if manufacturer provide too much service □Strongly disagree □Disagree □Neutral □Agree □Strongly agree	2. I feel unpleasant if manufacturer provide too much service □Strongly disagree □Disagree □Neutral □Agree □Strongly agree
3. I need product instruction book □Strongly disagree □Disagree □Neutral □Agree □Strongly agree 3a. Is there such a service in reality? □Yes □No (Please go to 3c) 3b. In reality, this service can meet my expectation □Strongly disagree □Disagree □Neutral □Agree □Strongly agree 3c. I'm satisfied with the situation □Strongly disagree □Disagree □Neutral □Agree □Strongly agree	3. I need product instruction book □Strongly disagree □Disagree □Neutral □Agree □Strongly agree 3a. Is there such a service in reality? □Yes □No (Please go to 3c) 3b. In reality, this service can meet my expectation □Strongly disagree □Disagree □Neutral □Agree □Strongly agree 3c. I'm satisfied with the situation □Strongly disagree □Disagree □Neutral □Agree □Strongly agree
4. I look forward to customer hotline □Strongly disagree □Disagree □Neutral □Agree □Strongly agree 4a. Is there such a service in reality? □Yes □No (Please go to 4c) 4b. In reality, this service can meet my expectation □Strongly disagree □Disagree □Neutral □Agree □Strongly agree 4c. I'm satisfied with the situation □Strongly disagree □Disagree □Neutral □Agree □Strongly agree	4. I look forward to customer hotline □Strongly disagree □Disagree □Neutral □Agree □Strongly agree 4a. Is there such a service in reality? □Yes □No (Please go to 4c) 4b. In reality, this service can meet my expectation □Strongly disagree □Disagree □Neutral □Agree □Strongly agree 4c. I'm satisfied with the situation □Strongly disagree □Disagree □Neutral □Agree □Strongly agree

5. I look forward a tutor to teach me how to use the product at the beginning stage □Strongly disagree □Disagree □Neutral □Agree □Strongly agree 5a. Is there such a service in reality? □Yes □No (Please go to 5c) 5b. In reality, this service can meet my expectation □Strongly disagree □Disagree □Neutral □Agree □Strongly agree 5c. I'm satisfied with the situation □Strongly disagree □Disagree □Neutral □Agree □Strongly agree	5. I look forward a tutor to teach me how to use the product at the beginning stage □Strongly disagree □Disagree □Neutral □Agree □Strongly agree 5a. Is there such a service in reality? □Yes □No (Please go to 5c) 5b. In reality, this service can meet my expectation □Strongly disagree □Disagree □Neutral □Agree □Strongly agree 5c. I'm satisfied with the situation □Strongly disagree □Disagree □Neutral □Agree □Strongly agree
6. I look forward a tutor to teach me how to use the product at all times □Strongly disagree □Disagree □Neutral □Agree □Strongly agree 6a. Is there such a service in reality? □Yes □No (Please go to 4c) 6b. In reality, this service can meet my expectation □Strongly disagree □Disagree □Neutral □Agree □Strongly agree 6c. I'm satisfied with the situation □Strongly disagree □Disagree □Neutral □Agree □Strongly agree	6. I look forward a tutor to teach me how to use the product at all times □Strongly disagree □Disagree □Neutral □Agree □Strongly agree 6a. Is there such a service in reality? □Yes □No (Please go to 4c) 6b. In reality, this service can meet my expectation □Strongly disagree □Disagree □Neutral □Agree □Strongly agree 6c. I'm satisfied with the situation □Strongly disagree □Disagree □Neutral □Agree □Strongly agree

(E). Living condition

Family status

1. Do you live with a teenager aged 18 years old or below?
   □Yes □No
2. What's your main source of income at current stage? （can choose more than one option）
   □Labor income or wages □Savings, annuity, pensions □assets income（investment, rental income）
   □Relatives（such as the financial assistance from spouse/children）□Comprehensive Social Security Assistance(CSSA) Scheme
   □Old age allowance □Others, please specify
   _____
3. What's your current monthly income?
   □ No income □ Less than $5,000 (But still have income) □ $5,000 ~ $9,999 □ $10,000 ~ $14,999
   □ $15,000 ~ $19,999 □ $20,000 ~ $24,999 □ $25,000 ~ $29,999 □ $30,000 -$39,999
   □ $40,000 -$49,999 □ $50,000 -$59,999 □ $60,000 or above

Aging in place

4. I'm satisfied with the place I live.
   □Strongly unsatisfied □Unsatisfied □Natural □Satisfied □Strongly satisfied
5. Do you often leave the community where you live?
   □Never □Rarely □Occasionally □Usually
6. Do you feel you are close to the community where you live?
   □Very not close □Not close □Natural □Close □Very close
7. My family members or friends always visit me (More than twice a week)
   □Yes □No

end

If you are interested in helping with the follow-up research, please leave your contact information.

Name:
Gender:
Contact number:
Email address:

Appendix IV

Constructs, definition, items, and sources of measurement in Chapter 5

Constructs	Definition	Measurement Items	Sources
Behavioral Intention (BI)	A person's subjective assessment of the probability that he/she will perform some behavior	BI1: Intend to use/continue using AlipayHK in the future BI2: Will learn AlipayHK more in my daily life	(Venkatesh et al., 2003)
Perceived Usefulness (PU)	The degree to which a person believes that using a particular technology would enhance his or her life	PU1: Using AlipayHK would enhance my effectiveness in life PU2: Using technology would make my life more convenient PU3: I find AlipayHK is useful in my life	(Davis, 1989)
Perceived Ease of Use (PEOU)	The degree to which a person believes that using a particular technology would be free of effort	PEOU1: I find AlipayHK is easy to use PEOU2: I could be skilful at using AlipayHK	(Davis, 1989)
Perceived Enjoyment (PE)	The extent to which interacting with gamified system is perceived as fun, aside from any performance consequences	PE1: I find interacting with the gamified learning system to be enjoyable PE2: The actual process of interacting with the gamified learning system is pleasant PE3: I have fun when interacting with the gamified learning system	(Venkatesh & Davis, 2000)
Perceived Effectiveness of Gamification (PEG)	the extent to which the gamification facilitates their engagement with the technology that the user perceived and evaluated	PEG1: The gamified learning system can reduce my fear of learning new functions in AlipayHK PEG2: I like using the gamified learning system to learn AlipayHK PEG3: The gamified learning system facilitates the efficient use of AlipayHK PEG4: The gamified learning system improved my motivation to learn and use AlipayHK PEG5: The gamified learning system allows me to learn AlipayHK without the help from others	(Wong et al., 2021); (Rodrigues et al., 2016)
Self-perceived Knowledge (SPK)	A person's estimate of how much he/she know or have learned about the technology	SPK: The extent to which I know how to use AlipayHK	(Aggarwal et al., 2015)
Actual Knowledge (AK)	A person's actual knowledge, skills, and competence with the technology	AK: The score received from AlipayHK gamified learning system	(Aggarwal et al., 2015)

Appendix V

THE HONG KONG POLYTECHNIC UNIVERSITY
香港理工大學

INFORMATION SHEET

A GAMIFICATION APPROACH FOR ENHANCING OLDER ADULTS' TECHNOLOGY ADOPTION AND KNOWLEDGE TRANSFTER OF GERONTECHNOLOGY FOR AGING IN PLACE

You are invited to participate in the above project conducted by AN Siyang, who is a PhD student of the Department of Industrial and Systems Engineering in The Hong Kong Polytechnic University. The project has been approved by the PolyU Institutional Review Board (PolyU IRB) (or its Delegate) (Reference Number: HSEARS20211026010).

The aims of this project are enhancing older adults' gerontechnology acceptance through servitization process and assist manufacturers increase their understanding and satisfaction on old adults and improve their competitiveness.

You are invited to complete a questionnaire, which will take you about 10 minutes. You will then be asked to play some games to teach you how to use high-tech products. The whole investigation will take about 20 minutes.

The information you provide as part of the project is the research data. Any research data from which you can be identified is known as personal data. Personal data does not include data where the identity has been removed (anonymous data). We will minimize our use of personal data in the study as much as possible. The researcher and her team, supervisor, collaborator (including Prof. CHEUNG Chi Fai, AN Siyang, Cheng Mei Na, LO Yu Ting, HAU Ho Hin within Hong Kong and Prof. Kelvin Willoughby outside Hong Kong) will have access to personal data and research data for the purposes of the study. Responsible members of The Hong Kong Polytechnic University may be given access for monitoring and/or audit of the research.

All information related to you will remain confidential and (please provide information on how information will be kept and accessed, e.g., will be identifiable by codes only known to the researchers). The information collected will be kept until (please provide an expiry date or a reference to a milestone, like 2 years after project completion/publication or public release of research results). The Hong Kong Polytechnic University takes reasonable precautions to prevent the loss, misappropriation, unauthorized access or destruction of the information you provide.

You have every right to withdraw from the study before or during the measurement without penalty of any kind.

If you have any questions, you may ask our helpers now or later, even after the study has started. You may contact Prof. CHEUNG Chi Fai (tel. no.: +852 27667905/ email:

benny.cheung@) or AN Siyang (tel. no. +852 5229 /email: siyang.an@) of PolyU under the following situations:

a. if you have any other questions in relation to the study;
b. if, under very rare conditions, you become injured as a result of your participation in the study; or
c. if you want to get access to/or change your personal data before (the expiry date).

In the event you have any complaints about the conduct of this research study, you may contact Secretary, PolyU Institutional Review Board in writing (institutional.review.board@polyu.edu.hk) stating clearly the responsible person and department of this study as well as the Reference Number.

Thank you for your interest in participating in this study.

Prof. CHEUNG Chi Fai
Principal Investigator/Chief Investigator

Hung Hom Kowloon Hong Kong 香港 九龍 紅磡
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Appendix VI

Survey on older adults' views on gamification system of AlipayHK

Hello, we are the students from the Department of Industrial and Systems Engineering of the Hong Kong Polytechnic University. We are conducting a study on the effectiveness of gamification in increasing technology adoption among the middle-aged and older adults.

This survey is divided into three parts.

In the first part, you will be asked some questions related to your payment habits and your knowledgeof AlipayHK. In the second part, we will ask you to play a game to learn how to use AlipayHK. In the third part, you will be asked to answer some questions based on your experience after playing the game.

The whole process is expected to take you 5-10 minutes. All information will be kept confidential and will only be used for this study.

Part I: Payment habits and the use of AlipayHK

1. What is/are the payment method(s) you commonly use? [Multiple choice]*

□ Cash
□ Octopus
□ Bank Card / Credit Card
□ Mobile payment applications (e.g. WeChat, Alipay)
□ Other _____

2. Have you ever heard of **or used** AlipayHK? [Multiple choice] *

□ I don't know what it is
□ I have heard of it, but haven't downloaded and used it
□ Downloaded but not used yet
□ Only used once
□ Occasionally use
□ Frequently use

3. Which of the following functions of AlipayHK **have** you used or heard? [Multiple Choice] *

□ Pay or transfer money by scanning QR code
□ Top-up to AlipayHK
□ Transfer money to friends
□ Take transportations by EasyGo
□ Payment by payment code
□ I haven't used or heard of any functions mentioned above
□ Other_____

4. Do you know **how to use** AlipayHK?

Please rate on a scale of 1-10, with '1' indicating that you don't know how to use it at all and 10 indicating that you know how to use it proficiently [Single-choice] *

1 (don't know how to use it at all)	2	3	4	5	6	7	8	9	10 (know how to use it proficiently)

5. Do you plan to **use** AlipayHK in **the future**? [Matrix Scale Questions] *

	Strongly disagree						Strongly agree
1) I am going to use AlipayHK in the future	1	2	3	4	5	6	7
2) I will learn more about or use AlipayHK more in my daily life	1	2	3	4	5	6	7

6. **How did you learn** or **how do you plan to learn** AlipayHK? [Multiple Choice] *

□ Learn by yourself through the information provided by AlipayHK
□ Learn by yourself through other channels (e.g., search the tutorials from website)
□ Seek help and teaching from others
□ Other _____

7. Do you think AlipayHK is a **useful** app? [Matrix Scale Questions] *

	Strongly disagree						Strongly agree
1) Using AlipayHK can enhance the efficiency in my life	1	2	3	4	5	6	7
2) Using AlipayHK can make my life more convenient	1	2	3	4	5	6	7
3) I find AlipayHK is useful in my life	1	2	3	4	5	6	7

8. Do you think AlipayHK is **easy to use**? [Matrix Scale Questions] *

	Strongly disagree						Strongly agree
1) I found AlipayHK is easy to use	1	2	3	4	5	6	7
2) Learning to use AlipayHK is easy for me	1	2	3	4	5	6	7

Part 2: The AlipayHK game experience

Please indicate to the researcher that you have completed the first part of the questionnaire and the researcherwill provide you with a link of the instructional game of AlipayHK

What is your game **score**? [fill in the blank] *

_____

Part 3: Post-Game Opinions and Attitudes

After playing the game, please answer following questions based on your current opinions on AlipayHK and this gamified instruction.

1. After playing the game, do you now know **how to use** AlipayHK?

Please rate on a scale of 1-10, with '1' indicating that you don't know how to use it at all and 10 indicating that you know how to use it proficiently [Single-choice] *

1 (don't know how to use it at all)	2	3	4	5	6	7	8	9	10 (know how to use it proficiently)

2. Do you now think AlipayHK is a **useful** app? [Matrix Scale Questions] *

	Strongly disagree						Strongly agree
1) Using AlipayHK can enhance the efficiency in my life	1	2	3	4	5	6	7
2) Using AlipayHK can make my life more convenient	1	2	3	4	5	6	7
3) I find AlipayHK is useful in my life	1	2	3	4	5	6	7

3. Do you now think AlipayHK is **easy to use**? [Matrix Scale Questions] *

	Strongly disagree						Strongly agree
1) I found AlipayHK is easy to use	1	2	3	4	5	6	7
2) Learning to use AlipayHK is easy for me	1	2	3	4	5	6	7

4. Do you now **plan to use** AlipayHK in the future? [Matrix Scale Questions] *

	Strongly disagree						Strongly agree
1) I am going to use AlipayHK in the future	1	2	3	4	5	6	7
2) I will learn more about or use AlipayHK more in my daily life	1	2	3	4	5	6	7

5. Do you enjoy this gamified instruction? [Matrix Scale Questions] *

	Strongly disagree						Strongly agree
(1) I enjoyed myself during this process	1	2	3	4	5	6	7
(2) I was happy during the process	1	2	3	4	5	6	7
(3) This gamified instruction is fun	1	2	3	4	5	6	7

6. What's your opinion about this **gamified** approach to learning AlipayHK? [Matrix Scale Questions] *

	Strongly disagree						Strongly agree
1) Gamified learning approaches can reduce the fear to learn new technology.	1	2	3	4	5	6	7
2) I like this gamified approach to learn	1	2	3	4	5	6	7
3) I believe this approach can bring me better learning results	1	2	3	4	5	6	7
4) I have a higher motivation to learn AlipayHK by this way	1	2	3	4	5	6	7
5) By this approach, I can learn it without others' help or teaching	1	2	3	4	5	6	7

Basic Information

1. Age [multiple choice]*

□ 50-54
□ 55-59
□ 60-64
□ 65-69
□ 70-74
□ 75 or above

2. Gender [multiple choice]*

□ Male
□ Female

3. Your level of education [multiple choice]*

□ Informal/pre-primary
□ Primary
□ Secondary
□ Post-secondary
□ Degree or above

4. What is the approximate monthly per capita income of your family household? [Multiple choice]*

□ less than 5,000
□ 5,000-9,999
□ 10,000-19,999
□ 20,000-29,999
□ 30,000-39,999
□ 40,000-49,999
□ 50,000 or more