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Digital Dividend or Digital Divide? Improvement Strategies of Digital Health for Elderly Patients with Chronic Diseases in Shanghai

ZHAO Liebin

Doctor of Management

Supervisors:
PhD Abilio Oliveira, Associate Professor,
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PhD Jiang Hong, Professor,
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BUSINESS
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Marketing, Operations and General Management Department

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Digital Dividend or Digital Divide? Improvement Strategies of Digital Health for Elderly Patients with Chronic Diseases in Shanghai

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Abstract

Average life expectancy is increasing, and the ageing process is becoming longer, requiring greater healthcare for the elderly population, which has a very high incidence of chronic diseases. Digital health technology is also rapidly developing, and researchers analyze technologies that may promote people's healthcare. Our investigation is focused on elderly patients with chronic diseases in China – particularly in Shanghai. What are the perceptions and needs of elderly chronic disease patients about digital health technologies? And what are the influencing factors to adopt digital health applications by these patients? Having these starting questions, and after a deep literature review, we planned research integrating three studies considering elderly chronic disease patients: 1) a documental study, mainly to verify how the service strategies and digital health technologies have been approached in scientific research – analyzing relevant papers/studies published in the last years –, complementing the literature review; 2) a qualitative study, with focus groups (N=15), to identify the types of digital health application scenarios and how they are used, and also identify the needs of this population for digital health technology; 3) a quantitative study, with a questionnaire (N=1222), to propose and validate a KAP-UTAUT conceptual model, using SEM, to explain the adoption of digital health technologies. Technology anxiety, effort expectations, and performance expectations are the factors that may most affect it. Our research provides new theoretical guidance for the elderly population to utilize digital health technology better and provides essential references for the optimization of digital health technology, policy, and social environment improvement.

Keywords: Digital health, Elderly, Chronic diseases, Technology influence factors, Technology acceptance in health

JEL: I12, O33

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Resumo

A esperança média de vida está a aumentar e o processo de envelhecimento é progressivamente mais prolongado, exigindo maiores cuidados de saúde à população idosa, que tem uma incidência elevada de doenças crónicas. A tecnologia digital na saúde também se desenvolve rapidamente, analisando-se tecnologias que promovam os cuidados de saúde. Esta investigação centra-se em pacientes idosos com doenças crónicas em Shangai, na China. Quais são as percepções e necessidades dos idosos com doenças crónicas sobre as tecnologias digitais na saúde? Quais os fatores que influenciam a adoção de aplicações digitais por esses pacientes? Partindo destas questões, e após revisão da literatura, planeámos uma pesquisa com três estudos, considerando pacientes idosos com doenças crónicas: 1) um estudo documental, para verificar como as estratégias de serviços e tecnologias digitais em saúde têm sido abordadas – analisando artigos/estudos relevantes publicados nos últimos anos –, complementando a revisão da literatura; 2) estudo qualitativo, com grupos focais (N=15), para identificar os cenários de aplicações digitais em saúde, como são utilizados, e quais as necessidades dessa população por tecnologias digitais em saúde; 3) estudo quantitativo, com questionário (N=1222), para propor e validar um modelo concetual KAP-UTAUT, para explicar a adoção de tecnologias digitais em saúde. A ansiedade tecnológica, as expectativas de esforço e desempenho são os fatores que mais podem afetar a sua adoção. Este trabalho contribui com novas orientações para a população idosa utilizar melhor as tecnologias digitais em saúde, com referências importantes para a sua otimização, para políticas públicas e melhoria do ambiente social.

Palavras-chave: Saúde digital, Idoso, Doenças crónicas, Fatores de influência da tecnologia, Aceitação de tecnologia em saúde
JEL: I12, O33

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摘 要

人们的平均寿命不断延长，老龄化进程也越来越长，这就要求为慢性病发病率高的老年人群提供更多的医疗卫生服务。数字健康技术也在迅速发展，研究人员对可能促进人们医疗卫生的技术进行了分析。我们的调查重点是中国--尤其是上海--的老年慢性病患者。老年慢性病患者对数字医疗技术的看法和需求是什么？这些患者采用数字医疗应用的影响因素是什么？带着这些问题，在深入查阅文献后，我们计划开展三项针对老年慢性病患者的研究： 1）文献研究，主要是为了验证科学研究是如何对待服务策略和数字健康技术的--分析过去几年发表的相关论文/研究--作为对文献综述的补充；2) 一项定性研究，通过焦点小组（15 人）确定数字健康应用场景的类型及其使用方式，同时确定该人群对数字健康技术的需求；3) 一项定量研究，通过问卷调查（1222 人）提出并验证 KAP-UTAUT 概念模型，使用 SEM 解释数字健康技术的采用情况。技术焦虑、努力预期和绩效 预期是可能对其影响最大的因素。我们的研究为老年人群更好地利用数字健康技术提供了新的理论指导，也为数字健康技术的优化、政策和社会环境的改善提供了重要参考。

关键词：数字健康，老年人，慢性疾病，技术影响因素，卫生技术接受度

JEL: I12, O33

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List of Abbreviations

BI, Behavioral Intention

COPD, Chronic Obstructive Pulmonary Disease

DH, Digital Health

EE, Effort Expectancy

FC, Facilitating Conditions

ICT, Information and Communication Technology

KAP, Knowledge-Attitude-Practice theory

PE, Performance Expectancy

SEM, Structured Equation Modeling

SI, Social Influence

TA, Technology Anxiety

TAM, Technology Acceptance Model

UB, Use Behavior

UTAUT, Unified Theory of Acceptance and Use of Technology

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Chapter 1: Introduction

1.1 General introduction – research topic delimitation

The global issue of aging populations is becoming increasingly prominent, with a continuous expansion of the base of patients suffering from chronic diseases worldwide. The prevalence of chronic diseases in the elderly far exceeds that of the general population, posing a serious threat to the quality of life and overall health of the elderly.

China is on the verge of entering a moderately aged society, with an aging rate significantly higher than the global average. This is characterized by a large elderly population, a rapidly progressing aging process, and noticeable urban-rural disparities. According to data from the fifth China Health Service Survey in 2018, the prevalence of chronic diseases in the elderly was 71.8%. The number of elderly patients with chronic diseases is increasing year by year, and the size of the ageing population is expanding, however, the social service system for the elderly is not perfect enough, which seriously increases the economic burden of disease on the patient's family and society (Bähler et al., 2015; Ho et al., 2017).

The continuous innovation in information technology is propelling traditional chronic disease care models into a new era of digital health, which is expected to enhance the effectiveness of self-health management for elderly individuals with chronic diseases. In October 2019, the World Health Organization released the 'Global Strategy on Digital Health (2020 - 2024)', encouraging nations worldwide to actively promote innovation and application in the field of digital health (World Health Organization, 2021). This aims to improve healthcare communication and management efficiency for elderly individuals with chronic diseases, reduce healthcare costs, and minimize medical errors. The application of digital health technology in the field of chronic diseases in the elderly has garnered comprehensive attention (Stellefson et al., 2013; Tistad et al., 2018).

The Chinese government has elevated the development of new forms of digital health to the national strategic level, making extensive use of information technologies such as the Internet, the Internet of Things, and big data. This includes developing and promoting suitable digital health technologies and supporting tools, such as wearable devices, artificial intelligence-assisted diagnostic systems, remote medical platforms, and mobile health management systems. China is actively exploring the 'Smart Trinity' strategy for digital health development, which includes intelligent clinical diagnosis and treatment systems, intelligent patient medical service systems, and intelligent hospital management systems. However, as the application of digital health technology expands, concerns about the digital health divide are also growing, particularly among elderly populations with a high prevalence of chronic diseases.

Like other developing countries, China lacks research on the application of digital health technology to the elderly population with chronic diseases. Whether digital health technology brings dividends or widens the gap for this demographic remains uncertain. What are the influencing factors of this technology in practical application? How can more effective strategies for implementing digital health technology be formulated? In-depth research is necessary to find optimal answers to these questions.

1.2 Motivation

Based on the rapid development of information and communication technology, emerging digital health technology has brought new opportunities to modern medicine. Countries worldwide are actively promoting relevant research to comprehensively understand the impact of this novel technology on diverse populations in disease diagnosis, treatment, and health management. Population aging is a significant global challenge faced in today's world, with chronic diseases posing a serious threat to the life and health of the elderly population, thereby presenting a major challenge in the field of modern medicine.

As a hospital administrator, the researcher has multiple professional motivations to study the acceptance of digital health in the geriatric population. With the continuous development of digital health technology, the healthcare industry is experiencing profound changes, and this research will help administrators to understand the current status of the adoption of digital health technology among the older population and suggest supportive strategies for hospitals to improve their services in a targeted manner to increase the acceptance of digital health technology among the older population.

The rapid development of digital health technology has become a significant trend in contemporary society, particularly in the healthcare domain. Elderly individuals with chronic diseases exhibit a high dependency on healthcare systems. Applying digital health to this population raises questions about whether it brings dividends or widens existing gaps. Presently, research in this area in China needs to be improved.

In the face of the rapidly advancing digital health systems, there is an urgent need to conduct targeted research on applying digital health technology to the elderly population with chronic diseases.

1.3 Research problem

China has the largest population in the world, and the largest elderly population. The speed of population ageing and the size of the elderly population are rarely seen in the history of world population development (Z. Deng, 2021). According to China's National Bureau of Statistics, the proportion of the elderly population aged 60 and above was 13.3 per cent in 2010 and had risen to 17.3 per cent by 2017 (Hu et al., 2021). From 1999 to 2017, the net increase in China's elderly population was 110 million (Feng et al., 2020). The elderly population has become a high prevalence of chronic diseases.

According to data from the fifth National Health Service Survey in 2018, the prevalence of chronic diseases among older people was 71.8 per cent, with the prevalence of chronic diseases among older people in urban areas significantly higher than in rural areas (Wen et al., 2021). According to the 'China Aging and Health National Assessment Report' by the World Health Organization, the prevalence of hypertension among individuals aged 60 and above is 66.9%, diabetes is 19.6%, the chronic obstructive pulmonary disease is 15.5%, stroke is 5.7%, and coronary heart disease is 2.8% (World Health Organization, 2015).

The widespread application of a mature new technology requires in-depth research on individual users. With the rapid development of Information and Communication Technologies (ICT), especially the widespread ownership of smartphones, the groundwork has been laid for the deep application of digital health technologies. Numerous studies have affirmed the promising prospects of digital health technology, suggesting significant impacts on improving the health status of the elderly (Cao et al., 2022; W. Li et al., 2023). Some research indicate that the widespread application of digital health technology necessitates meticulous policy design, particularly involving various stakeholders such as service providers, policy designers, and especially end-users. Despite extensive global efforts in applying digital health technology, studies reveal that the utilization and frequency of mobile health technology are not high, especially among the elderly, who face significant challenges in accepting digital health technology (Hoque & Sorwar, 2017).

Moreover, there is limited systematic research on the application of digital health technology in China, particularly among the elderly, who have a high prevalence of various chronic diseases, resulting in a high dependency on the healthcare system. There needs to be more evaluation research on the application of digital health technology targeting this demographic, and even fewer studies have been conducted to optimize strategies based on empirical data.

The numerous challenges digital health technology faces in the elderly with chronic diseases cannot be overlooked. These challenges include the digital health literacy of elderly individuals with chronic diseases (Shin, 2019), the user-friendliness of digital health technology for elderly users (Portz et al., 2019), and the special attention of the elderly population to privacy protection (Andreou et al., 2022). Digital health is a broad conceptual category covering various application forms, and according to previous research findings, regional, cultural, and demographic differences exist in the methods, effects, and influencing factors of digital health technology. Developing countries lag Western developed countries regarding the quantity and scope of digital health research (Marcolino et al., 2018).

In China, the application and development of digital health technology are progressing incredibly fast at the national government, social, and health service levels. However, in sharp contrast, there is insufficient research on the adoption and acceptance of digital health technology, specifically among elderly individuals with chronic diseases.

Faced with all the challenges to go further, there is an urgent need to understand the application of digital health technology in China's elderly population with chronic diseases. This entails identifying relevant influencing factors and understanding the mechanisms that affect the acceptance and adoption of digital health technology. Effective strategies to enhance the application of digital health technology in the elderly population with chronic diseases in China can be formulated based on this understanding.

Our literature review revealed limited research on the aforementioned fields. The perceptions and needs of elderly chronic disease patients about digital health technologies and the influencing factors that affect the adoption of digital health applications by elderly chronic disease patients need to be further explored.

In the present social and public health context, it is very relevant to conduct this research, identify appropriate theoretical models, and provide better explanations and guidance for practice in the field of technology acceptance in public health. Our investigation may also be a reference in digital health development and have inspirational significance for developing countries also plagued by aging and with a high prevalence of chronic diseases.

1.4 Research questions and objectives

The main goal of our research is to to understand the application of digital health technology in the elderly chronic disease population in China, especially the relevant influencing factors, and strategies to improve the effectiveness of digital health applications. Thus, we propose the following research questions:

(1) What are the perceptions and needs of elderly chronic disease patients about digital health technologies (in different scenarios)?

(2) What are the influencing factors (facilitators and barriers) that affect the adoption of digital health applications by elderly chronic disease patients?

As mentioned previously (cf. section 1.3), some countries have researched the application of digital health technology for different populations. However, China has conducted relatively limited research in this regard. Along with the increasing penetration of digital health technologies in healthcare services for the elderly chronic disease population, we need to know more about the changes and impacts of digital health technologies on these patients: what are the main digital health scenarios faced by this group of individuals? How do elderly chronic patients feel about digital health? What are the needs and challenges of these groups for digital health? – After complementing the literature review with a documental study (Study 1), we strive to answer these questions in a qualitative study (Study 2).

Having several theoretical-conceptual models for evaluating digital health technologies, in different contexts, the proposal of a conceptual model for assessing its applicability in Chinese elderly individuals with chronic diseases is essential. It needs to be more research in this area, so, we investigate which theoretical-conceptual model is more suitable for this research and evaluation – and propose a new one. How do the involved variables – latent variables – affect the acceptance and use of digital health technologies by elderly chronic disease patients? – In sequence of the previous studies, we answer to this question in a quantitative study (Study 3).

In sum, the current research focuses on service strategies for elderly individuals with chronic diseases in the context of China's digital health policy. Based on the research questions, six objectives are proposed, according to the three planned studies: (Study 1 – Documental or Bibliographical, to complement the literature review).

(1) Verify how the service strategies and digital health technologies for elderly individuals with chronic diseases have been approached in scientific research (in 2014-2022, as during this period, according to literature, the development and application of digital health technology

have entered a fast lane).

(Study 2 – Qualitative, Focus group discussions)

(2) Identify the types of digital health application scenarios and the utilization of digital health technology by elderly chronic disease patients in Shanghai.

(3) Identify the needs of elderly chronic disease patients for digital health technology and application scenarios.

(Study 3 – Quantitative, Inferential using SEM – Structured Equation Modeling)

(4) Propose – and validate – a theoretical-conceptual model to explain the acceptance and use of digital health technologies by elderly chronic disease patients.

(5) Identify the factors that affect the acceptance and use of digital health technologies by elderly chronic disease patients.

(6) Propose suggestions to facilitate the adoption of digital health technologies by elderly chronic disease patients.

1.5 Methodological approach – research purpose

The question arises whether digital health applications have brought benefits or gaps to the elderly with chronic diseases. The purpose of this study is to clarify the views and experiences of elderly patients with chronic diseases on digital health, determine an appropriate theoretical model, evaluate the factors that affect the acceptance and use of digital health technology by this group, and propose improvement strategies, so as to provide an evidence-based policy basis for better promoting this health strategy in developing countries under the background of aging, the high incidence rate of chronic diseases, and rapid development of digital health.

1.6 Research plan

This study focuses on the elderly population with chronic diseases in Shanghai, investigating whether digital health technology has a positive or negative impact on this group, and further exploring possible improvement strategies.

The entire research plan revolves around this research objective. After preliminary literature review, the framework of the research plan has been developed.

Firstly, literature research will be conducted around concepts and categories related to digital health, the current status and policies of digital health, especially the practical situation in China and Shanghai, as well as the application of digital health in the elderly population with chronic diseases.

Secondly, the research will focus on two aspects: the views and needs of elderly chronic disease patients on digital health applications in different scenarios, as well as related influencing factors.

Thirdly, six research objectives should be clarified: to scientifically evaluate the service strategies of digital health technology for the research group, to study the types of digital health application scenarios and service utilization for the elderly with chronic diseases in Shanghai, to clarify the needs of elderly patients with chronic diseases in the utilization of digital health technology, to explain the acceptance and use of digital health technology by this group using appropriate theoretical models, to clarify the influencing factors of the acceptance and use of digital health technology by the elderly with chronic diseases, and to propose suggestions to help elderly patients with chronic diseases better utilize digital health technology.

Finally, based on the above research objectives, three study projects are planned to be conducted for exploration, including literature screening, descriptive analysis, and qualitative research, to preliminarily determine the concepts, current situation, pain points, and theoretical models in this research field. Based on these research conclusions, further directions for subsequent studies will be outlined. Through focus group discussions and qualitative research, more rich information and clues can be obtained from individual elderly chronic disease patients in the real world, further expanding the verification of issues and needs in this field, and using these results as important evidence for subsequent analysis and interpretation of the problem. By selecting and determining appropriate theoretical models, setting inference hypotheses, conducting quantitative research, selecting and improving appropriate survey questionnaires based on the established models and variables, conducting questionnaire surveys, verifying the results of various variables in the model, evaluating and analyzing the validity of hypotheses, and the interrelationships of various variables in the model, analyzing various factors that affect the acceptance and use of digital health technology by elderly chronic disease patients, explaining the reasons for these phenomena, and inferring and deducing possible countermeasures and suggestions for the future.

Figure 1.1 lists the interrelationships and working modes of various parts of this research plan.

Title

Digital support or digital divide: Strategies to improve digital health applications and services for elderly patients with chronic diseases, in Shanghai

Literature review

Global aging and chronic diseases	Digital health applications and elderly chronic diseases	Digital health application policies in China	Technology acceptance models (including in public health research)	Digital health applications and services for elderly patients

Population

(Main Participants: elderly chronic disease patients, in Shanghai)

Research questions

What are the perceptions and needs of elderly chronic disease patients about digital health technologies (in different scenarios)?	What are the influencing factors that affect the adoption of digital health applications by elderly chronic disease patients?

Main Objectives

1. Verify how the service strategies and digital health technologies have been approached in scientific research.	**2.** Identify the types of digital health application scenarios and the use of digital health technology	**3.** Identify the needs of elderly chronic disease patients for digital health technology and application scenarios.	**4.** Propose and validate a conceptual model to explain the acceptance and use of digital health technologies by elderly chronic disease patients.	**5.** Identify the factors that affect the acceptance and use of digital health technologies.	**6.** Propose suggestions to facilitate the adoption of digital health technologies by elderly chronic disease patients.

Studies

1. Documental – Qualitative Bibliographical study – Select scientific papers that enrich the literature review (with a meta-analysis), giving findings, through descriptive analysis and qualitative research, that contribute to determine the pain points in the present scien-tific field, and redefine the subsequent studies.	**2.** Focus group – Qualitative Focus group discussions – The interview outline is based on the topics or concepts obtained from the previous study and the literature review, using nVivo for textual data analysis and the grounded theory to interpret the results.	**3.** Inferential – Quantitative A questionnaire was developed to evaluate the variables (and their causal relations) in a proposed conceptual model to explain the adoption of digital health technologies by elderly chronic disease patients. The data are analyzed by statistical techniques, through SPSS and Smartpls – using SEM (Structured Equation Model).

Figure1.1 Research plan

1.7 Thesis structure

This research report is divided into eight chapters. Against aging and the high incidence of chronic diseases becoming severe global health challenges, digital health has become an important development strategy for countries worldwide. In Chapter 1, we introduce the main areas and issues involved in this research based on the above opportunities and challenges. We also introduce the research motivation, research questions, objectives, research plan, methodological approach, research design process, and calendar. For the literature review, in Chapter 2, we provide an overall overview of global aging, chronic diseases, and digital health applications using data from various countries around the world, including China. This chapter also presents a brief review of KAP model and several relevant technology acceptance models.

Chapter 2 provides readers with a general understanding of the research field through a deep literature review centered on the topics of global aging and elderly chronic diseases, digital health applications in particular for elderly patients, and technology acceptance models.

Moreover, Chapter 3 introduces the design and methodological approach, including how we control the quality of the three planned studies. Chapter 4 serves as a supplementary chapter, consisting of a documental study in which 31 articles were selected from major global databases, and descriptive research and qualitative analysis were conducted on these articles. A literature-based summary was conducted around the scenarios, needs, promoting factors, and obstacles involved in the application of digital health for chronic elderly diseases. Although this work provides us with a bird's-eye view of our research field based on previous studies, it also raises a new proposition that research in the field of digital health for elderly chronic patients in developing countries such as China is still far from sufficient and requires real-world data to evaluate the impact of digital health technology on elderly chronic patients, there is also a need for scientific theories to better guide the promotion and application of digital health technology. Based on the integration of the classic theory of knowledge, attitude, and practice in the field of health communication, we proposed an integrated model, KAP-UTAUT, and designed two real-world studies – one qualitative, having focus group discussions with small samples, and another quantitative, by questionnaire, with multi center large samples, to test and validate this new conceptual model (or the integrated KAP-UTAUT model), by exploring, verifying, and explaining the model hypotheses. The specific objectives, methods, and results of the three studies are elaborated in Chapters 4, 5 and 6 of this thesis.

The seventh Chapter provides a comprehensive discussion of the research results, which revolves around the results of model validation based on questionnaire surveys. It integrates various findings from literature research and focus group discussions to explain the mutual influence and mechanism of action between variables in the KAP-UTAUT model.

The last chapter presents the Conclusions, which provides a comprehensive summary of the research from two aspects: theoretical value and inspiration for practical application.

Chapter 2: Literature Review (Part One)

2.1 Global aging and chronic diseases

Since the beginning of the 21st century, population aging has emerged as a significant global challenge. Rapid advancements in medical technology have led to a substantial increase in life expectancy, propelling Western developed nations into heavily aged societies. In contrast, developing countries undergo a demographic transition toward lower birth and death rates. Consequently, the global process of population aging is accelerating continuously (Christensen et al., 2009; K. Zhang et al., 2022). In 2018, the worldwide population aged 60 and above reached 1.01 billion, constituting 13.1% of the global population. The World Health Organization estimates that by 2050, the elderly population will reach 2 billion, comprising 22% of the global population (World Health Organization, 2021). As the degree of population aging deepens, chronic non-communicable diseases pose a severe threat to human life and health. Globally, in 2019, all non-communicable diseases accounted for 74% of global deaths, with seven of the top ten leading causes of death being chronic non-communicable diseases, constituting 44% of all deaths. Due to the increasing number of elderly individuals, the base of global chronic disease patients continues to expand (Mattison et al., 2022).

Additionally, as most chronic diseases are lifelong, the diseases themselves and their complications pose long-term and potential hazards to patient health, significantly reducing the quality of life. This impact extends to the instrumental activities of daily living (IADLs) of elderly individuals (Schenker & Costa, 2019). Furthermore, the long-term medical and caregiving needs of patients entail frequent outpatient appointments, transportation obstacles, and the burden of disease treatment (Bähler et al., 2015; Fortin et al., 2006; Ho et al., 2017). Statistics indicate that in most countries, the diagnostic and treatment costs for elderly chronic disease patients increase significantly every year (Kapadia et al., 2015).

Since 1999, China has officially entered an aging society, and in the coming decades, the Chinese healthcare system will face significant challenges due to aging (Zhou et al., 2021). Currently, the rate of population aging in China is significantly higher than the global average. The country exhibits characteristics of a large elderly population, rapid aging processes, and noticeable urban-rural disparities. According to the seventh national population census data in

November 2020, the population aged 60 and above has reached 264 million, accounting for 18.7% of the total population. As the degree of population aging deepens, the management of chronic diseases in the Chinese elderly population becomes increasingly challenging. In 2008, data from the fourth National Health Service Survey in China indicated that among individuals aged 60 and above, the rate of illness without seeking medical attention within the past two weeks was 37%, and the proportion of those requiring hospitalization but not admitted was 23.9%, severely impacting the health status of the elderly population (Jin et al., 2021).

In 2013, China had 202 million people aged 60 and above, with over 100 million suffering from chronic non-communicable diseases and over 37 million elderly individuals with disabilities (X. Q. Wang & Chen, 2014). The fifth National Health Service Survey in 2018 revealed a chronic disease prevalence rate of 71.8% among the elderly, with urban areas significantly higher than rural areas (Feng et al., 2020). Given the relatively low level of socialisation of elderly care services in China, the increasing level of population ageing, the increasing number of elderly people suffering from chronic non-communicable diseases, and the large number of elderly patients in need of long-term maintenance medical care, this has brought a heavy economic burden of illness to the families of the patients and to society.

The prevalence of chronic diseases in the elderly population is significantly higher than that of the general population, with a staggering 77% occurrence rate of multiple chronic diseases (Bähler et al., 2015). According to the World Health Organisation, as of 2023, cardiovascular disease will be the most deadly disease in the world, with an average of 17.9 million deaths per year, cancer an average of 9.3 million deaths per year, chronic respiratory diseases an average of 4.1 million deaths per year, and diabetes an average of 2 million deaths per year, and these four groups of diseases account for more than 80 per cent of the deaths caused by all chronic non-communicable diseases and above (World Health Organization, 2015). The data from the China Health Statistics Yearbook (National Health Commission of the People's Republic of China, 2023) reveals that in 2018, the proportion of elderly individuals with chronic diseases surpassed the combined total of all other age groups, ranking first. The report particularly emphasizes that, when categorized by disease type, among the entire population, endocrine, nutritional, and metabolic diseases exhibited the highest prevalence, with diabetes being the most prevalent. In terms of circulatory system diseases, hypertension had the highest prevalence, followed by heart disease and cerebrovascular disease. Among respiratory system diseases, chronic bronchitis in the elderly had a relatively high prevalence, as detailed in Table 2.1.

Therefore, our scientific project focuses specifically on five major chronic diseases: hypertension, coronary heart disease, diabetes, stroke, and chronic obstructive pulmonary disease. Additionally, it is worth noting that tumors may differ from other chronic diseases due to differences in disease management and patient psychological states – and have not been included in this research.

Table 2.1 Chronic disease incidence rates among Chinese residents in 2018 (‰)

Disease Category	Subcategory	‰
Age Classification	15-24 years	36.6
	25-34 years	70.7
	35-44 years	150.6
	45-54 years	312.6
	55-64 years	483.9
	65 years and above	623.3
Disease Type	Endocrine, Nutritional, and Metabolic Diseases (Total)	62.5
	Diabetes	53.1
	Circulatory System Diseases (Total)	251.0
	Hypertension	181.4
	Heart Disease	34.0
	Cerebrovascular Disease	22.9
	Respiratory System Diseases (Total)	26.1
	Chronic Bronchitis in the Elderly	9.6

2.2 Basic concepts of digital health

The concept of **digital health** can be traced back to the early 1970s when the World Health Organization (WHO) proposed that the use of information and communication technologies (ICTs) to increase patients' access to medical information and thereby improve their health began to gain attention in the 1990s with the development of the Internet and ICT-based technologies. E-health is an umbrella term for a set of ICT-based tools that are used to improve the state of the art and quality of healthcare, and thus support and enhance the diagnosis, treatment, prevention and home management of patients' health and lifestyle (Geissbühler, 2012).

In May 2005, the WHO first proposed the concept of digital health at the 58th World Health Assembly. Digital health is the use of information and communication technology to support health and related areas, including healthcare services, health surveillance, health literature, health education, knowledge, and research. The introduction of this concept marked the official inclusion of digital health in the WHO's work scope and opened the digital era of global healthcare. Since 2015, the concept of digital health has gradually become clearer and more unified overseas. The European Union defines digital health as "the use of advanced information and communication technologies to meet the needs of ordinary citizens, patients, healthcare providers, and healthcare policymakers" (Quaglio et al., 2016).

The Food and Drug Administration (FDA) of the United States broadly considers digital health to include "mobile health, health information technology, wearable devices, telehealth, remote medical care, and personalized medicine" (Khirasaria et al., 2020). WHO's Global Strategy on Digital Health (2020-2025) understands digital health as "the field of knowledge and practice related to the development and use of digital technologies to improve health" (World Health Organization, 2021).

China started its research on digital health relatively late. Scholars believe that digital health is "a new type of health service that is deeply integrated with traditional health and medical services, formed through the deep integration of the internet as a carrier, information and communication technologies such as mobile communication, the Internet of Things, cloud computing, and big data" (Huang & Jing, 2022).

Along the literature review we found that the main categories of digital health technology applications are mHealth, Telemedicine, Internet Medical and Smart Wearable Device.

mHealth is an application field of digital health. The Global eHealth Observatory Alliance defines mHealth as a new paradigm for advancing the practice of healthcare and public health services by relying on a variety of mobile technologies and devices, such as smartphones, patient monitoring devices, and other wireless communication technology equipment. The core of this concept is the deep integration of telemedicine technology and modern smartphone functionality, which enables real-time and accurate patient-physician interactions, either through the automatic collection of user vital signs data by embedded wearable devices or the manual entry of health information by users themselves, thus enhancing the convenience and responsiveness of healthcare services. mHealth encompasses a wide range of healthcare domains, including individualized health mHealth covers a wide range of healthcare areas, including the design and implementation of individualized health management programs and the tracking and monitoring of the spread of infectious and chronic diseases. With the advancement of technology and the growth of market demand, mHealth has become one of the most important driving forces in the transformation of the global healthcare industry (Tas et al., 2023).

Telemedicine is an important component of digital health, The World Health Organization (WHO) has given an authoritative definition of telemedicine, depicting it as a way for medical professionals to achieve a full range of medical services such as diagnostic communication, disease treatment and prevention, scientific research and evaluation, and continuous medical education and training, with the help of information and communication technology means and under geographically separated conditions (World Health Organization, 2021). Telemedicine fully mobilises the high-end medical technology and equipment resources of large medical centres to provide real-time and accurate telemedicine information and service support for the needs of regions with relatively scarce medical conditions as well as special environments. This largely eases the problems caused by the uneven geographical distribution of medical resources, allowing doctors to transcend the limitations of geographic regions and realize the instant sharing of medical records and diagnostic images. This innovative model promotes the fairness and accessibility of medical services and opens a whole new path for the development of global health (Ahmed et al., 2023).

Internet Medical The rapid development of the digital health field is reflected in a number of innovative applications, the core of which lies in relying on the Internet as a powerful carrier, making full use of advanced electronic information technology, and constructing a diversified health service platform integrating online health education, electronic health record management, real-time querying of medical information, personalized risk assessment of diseases, and generation of e-prescription, etc., which is changing the traditional medical service model at an unprecedented speed. It is changing the traditional medical service mode at an unprecedented speed (Mitek, 2022). Internet healthcare makes full use of the advantages of online booking and online medical services, deeply optimizes the original medical process and doctor-patient interaction, maximizes the effectiveness of doctors' professional services, and is committed to creating the best medical experience environment for patients. Nowadays, the application scope of Internet healthcare is expanding and has deeply penetrated all aspects of health management, effectively cutting down the additional costs incurred in the traditional process of medical treatment, and further enhancing the convenience and satisfaction of patients, thus promoting the efficient and humane process of medical services as a whole (De la Torre-Díez et al., 2015).

Smart Wearable Device is an exploration of the interaction between humans and technology, mainly using the human body as a carrier and through portable wearables to achieve interaction between the device and the human body (Tran et al., 2023). By virtue of its unique wearing convenience, intelligent function integration and specialised health monitoring capability, smart wearable devices cleverly integrate safe, reliable and tiny high-tech components into the product form, which can be closely adapted to the human body, equipped with a variety of high-precision sensors, continuously and real-time monitoring of a number of key physiological indicators of the human body, such as blood glucose level, blood pressure, body temperature, sleep quality, blood oxygen saturation, etc. With the technical support of big data, cloud storage and other statistical analysis through modelling, data mining and other statistical analysis, promoting medical information data transmission, providing real-time and comprehensive data support for medical and health services. Quality of blood sugar, blood pressure, body temperature, sleep quality, oxygen saturation, etc. Under the technical support of big data, cloud storage and other technologies, it facilitates the transmission of medical information data through modelling, data mining and other statistical analyses, providing real-time and comprehensive data support for medical and health services (Cheng et al., 2021).

2.3 Digital health applications and elderly chronic diseases

In the 21st century, global aging has become a significant challenge faced by societies worldwide. The World Health Organization (WHO) has proposed the goal of "Healthy Aging" and formulated the "Global Strategy and Action Plan on Aging and Health 2016-2020". Additionally, the WHO is actively promoting the "Healthy Aging 2020-2030" plan (Rudnicka et al., 2020). The strategy emphasizes aligning healthcare systems with the health needs of the elderly, improving hospital design, optimizing processes, providing convenient medical services, conducting high-risk disease screenings, and delivering continuous medical care and education tailored to the needs of the aging population.

Chronic diseases are closely associated with individual behavioral risk factors such as smoking, alcohol consumption, unhealthy diet, and lack of exercise (Ng et al., 2020). Patients, particularly the elderly individuals, are increasingly required to take greater responsibility for their health by actively changing unhealthy lifestyle habits to prevent long-term complications (Shrivastava et al., 2013). Reiners et al. (2019) found that addressing the healthcare challenges of elderly chronic disease patients extends beyond individual behavior, necessitating collective efforts from society to mobilize positive and favorable factors for chronic disease management. Individuals, families, communities, and society should actively participate in and benefit from the health management of elderly chronic disease patients.

With the rapid development of information technologies such as big data, the internet, and artificial intelligence, innovation in information technology is propelling traditional chronic disease care models into a new era of digital health. This evolution transcends temporal and spatial limitations, empowering elderly chronic disease patients to strengthen their self-health management (Forkner-Dunn, 2003; Stellefson et al., 2013; Tistad et al., 2018).

The World Health Organization proposed that the application of digital technologies should comprehensively cover eHealth, mHealth and cutting-edge areas such as artificial intelligence, big data and advanced technologies such as the Internet of Things (IoT) and cloud computing

(World Health Organization, 2021). This strategy not only deepens the connotation of the concept of eHealth and broadens its boundaries to more types of smart devices and connected technology users, but also establishes the strategic priority of digital health and puts forward strategic objectives and action guidelines to promote the development of digital health on a global scale. The scope of application of digital health technology is very wide and has great potential for future development. In personal health management, the promotion and application of digital health technology is of greater value to elderly patients with chronic diseases (Tistad et al., 2018). Enhancing the adaptability of elderly patients to digital health is crucial for achieving the goal of "Healthy Aging". It holds positive implications for maintaining the health status of the aging population (Y. Zhang et al., 2021).

Since 2022, countries worldwide have actively planned and implemented innovations and applications in digital health. Integrating elements such as policies, technology, products, and operations have propelled significant progress in digital health. Extensive exploration and research have been conducted in the domain of elderly chronic diseases (Renzi et al., 2022). Applying digital health technology in healthcare can enhance communication and management efficiency, improve healthcare quality, reduce healthcare costs, minimize medical errors, and promote healthcare equity (Renzi et al., 2022; Sharifi et al., 2013). Digital health technology not only records real-time information on the health status of older people, enabling healthcare professionals to quickly provide accurate and personalized health guidance and care plans based on up-to-date data, but also provides timely and effective assistance to older people when they face safety risks (Curtis & Price, 2017).

In predicting chronic diseases, Gaw (2016) found that guiding physical activity or dietary control through digital health technology can prevent the further deterioration of diseases such as type 2 diabetes. Monitoring changes in the daily life patterns of elderly individuals and analyzing their physical and cognitive function can serve as an early warning for diseases like dementia. Eriksson-Backa et al. (2018) argued that behaviors such as exercising, maintaining a healthy diet, and abstaining from certain foods play a crucial role in the health of elderly chronic disease patients. Positive lifestyle habits and seeking health information can provide more accurate predictions for potential future diseases.

Additionally, with the latest advancements in artificial intelligence technology, large language models may bring about new transformations in the medical field. Some scholars suggest that large generative language models, represented by ChatGPT – and other AI generative platforms –, could positively contribute to health education, disease management, and support for healthy lifestyles. This could enhance the interaction between healthcare providers and elderly chronic disease patients (Singhal et al., 2023).

With the widespread application of digital health technology in the elderly chronic disease population, the issue of the digital health divide has garnered increasing attention. The digital health divide refers to the dispersion of patient health data across various domains, hindering effective decision-making based on this data and preventing realizing the expected scale of digital health applications (Saeed & Masters, 2021). Shin (2019) found that the digital storage of health data and information created efficacy biases in the public's perception of digital health applications. Patients successfully using the applications could achieve a better healthcare experience, while those facing difficulties in application usage would struggle to meet their health needs.

Digital health literacy is the ability to evaluate health information from digital devices and apply the acquired knowledge to address or solve health-related problems. Good digital health literacy can encourage older adults to accept better and use digital health technology. However, those lacking knowledge of electronic health are often the elderly, who are more likely to suffer from chronic health conditions (Schulz et al., 2021). Elderly people with higher digital health literacy have more diversified sources of information, which enables them to have access to more diversified and rich health information content, increase their influence in social networks, accumulate and exchange more social capital in interpersonal networks, and form a rich and three-dimensional social network, which accelerates the effective diffusion and transmission of health information (Oh et al., 2021; Shi et al., 2023).

By maintaining physical health and participating in health resource sharing with the help of digital health technology, elderly patients with chronic diseases can sustainably improve their emotional satisfaction and self-efficacy, which further strengthens the social interaction ability and life health of elderly patients with chronic diseases (X. Wang & Luan, 2022).

2.4 Digital health application policies in China

Against the backdrop of an aging population and a persistent increase in the prevalence of chronic diseases, the Chinese government is actively exploring the application of digital health technology in medical health. This initiative aims to propel innovation and development within the national health system.

China has elevated the new paradigm of digital health to the national strategic level, explicitly outlining the construction of a national medical science and technology innovation system to advance medical technology.

The policy calls for developing and disseminating health-appropriate technologies and supporting tools. Supported by digital platforms, the initiative advocates using technologies such as artificial intelligence and big data to assist in building individual health profiles. While safeguarding individual privacy, these profiles aim to form personal health records, enabling real-time continuous health statuses. This, in turn, facilitates online management, early warning systems, and behavioral interventions for public health, ultimately enhancing public self-health management capabilities. The policy seeks to foster the development of "Internet + Medical Health", encouraging innovative service models.

Leveraging Internet technologies, the Internet of Things, big data, and other information technology tools, the policy emphasizes conducting high-quality, large-scale cohort studies. It encourages the research and development of wearable health smart devices and artificial intelligence-assisted diagnostic systems.

Relying on regional health information platforms, the initiative aims to advance "Internet + Public Health" services, fully utilizing digital information technology to enrich health management (M. Chen et al., 2021).

In November 2022, the National Health Commission released the "14th Five-Year Plan for National Health Informatization," explicitly mentioning the cultivation of new formats in the digital health economy (National Health Commission of the People's Republic of China, 2022). The plan focuses on advancing key areas of digital health industry development, emphasizing significant technological breakthroughs and development demands, enhancing competitiveness in critical links of the industry chain, and accelerating product and service iterations.

Simultaneously, the Chinese government actively explores the construction of smart hospitals. In 2018, the National Health Commission introduced the "Functional Application-Level Grading Evaluation Method and Standards for Electronic Medical Record Systems (Trial)" to achieve the unified integration of clinical information data in hospitals and enhance medical quality (National Health Commission of the People's Republic of China, 2018).

In 2019, the "Smart Hospital Service Grading Evaluation Standard System (Trial)" was launched, primarily aimed at evaluating the digital health services provided by hospitals and patients' perceptions of these services. This system serves as a crucial guiding document for the Chinese government in promoting digital health services across various levels of hospitals (National Health Commission of the People's Republic of China, 2019).

In 2021, the "Smart Hospital Management Grading Evaluation Standard System (Trial)" was introduced, focusing on a managerial perspective to promote the overall construction of hospitals and enhance their level of smart management (National Health Commission of the

People's Republic of China, 2021).

In conclusion, it is evident that China's policies related to digital health are being extensively implemented. There is an urgent need for research on the current acceptance and usage status of digital health technology among elderly chronic disease patients and their demands for digital health services. Given the relatively low level of socialization in China's elderly care services and the increasing population of elderly individuals with chronic diseases, the lack of research analyzing the acceptance of medical services by the elderly chronic disease population under the backdrop of China's digital health policies may hinder the improvement and perfection of China's health policies, thereby limiting the quality of medical services and health levels for elderly chronic disease patients.

2.5 Technology acceptance models (including in public health research)

In this section we present a brief review of KAP model and several relevant technology acceptance models including Theory of Reasoned Action, Theory of Planned Behaviour, Technology Acceptance Model, Integration Model of the Technology Acceptance Model and the Theory of Planned Behaviour, Motivational Model, Model of Personal Computer Utilization, Innovation Diffusion Theory, Social Cognitive Theory and Unified Theory of Acceptance and Use of Technology.

2.5.1 KAP model

The Knowledge, Attitude, and Practice Model (KAP model) originated in the field of social demography in the 1950s (Cleland, 1973; Ratcliffe, 1976). From the 1960s to the 1970s, in response to the requirements of primary healthcare approaches adopted by international aid organizations, the application of the KAP model for community perspectives and human behavior research saw a rapid increase.

Consequently, the KAP model solidified its position as a method for investigating health behavior and has since been widely used to gather information on healthcare-seeking behavior (Manderson & Aaby, 1992).

The classical theory in health communication, the KAP model, also known as the "knowledge-belief / attitude-behavior" theory, primarily used to explain the extent to which an individual's knowledge and beliefs influence health behaviour change (Glomsås et al., 2020). The theory divides the change in people's behaviour into three processes, which are the acquisition of knowledge, the creation of beliefs and the formation of behaviours (Li et al., 2015). In this context, knowledge refers to the ability to pursue and utilize information through understanding, experiential learning, and identification of learning techniques; attitude represents the response outcomes made in certain situations, observed and interpreted based on these responses, or combined into a viewpoint; behavior implies the combined influence of knowledge and habits (Badran, 1995). Stone and Campbell (1984) highlight the advantages of KAP surveys, including their simple design, quantifiable data, easily interpretable and concise results, generalizability of small sample outcomes to broader populations, cross-cultural comparability, quick execution, and ease of training.

2.5.2 Theory of reasoned action

In 1975, Fishbein and Ajzen (1977) proposed the Theory of Reasoned Action (TRA), primarily designed to elucidate the influence of behavioral attitudes and subjective norms on individual behavior. The theory posits that individuals are rational actors, suggesting that people engage in a comprehensive analysis of available information, contemplate the meaning and consequences of their actions, and then decide whether to adopt a specific behavior.

As illustrated in Annex A (Figure A.1), the TRA asserts that individual behavior is determined by behavioral intentions, which, in turn, are influenced by two factors: behavioral attitudes and subjective norms. Behavioral attitudes involve the individual's positive or negative emotions regarding the execution of a target behavior. This is determined by the rational evaluation of the individual concerning the positive or negative outcomes of the behavior and the perceived importance of these outcomes (Fishbein & Ajzen, 1977). On the other hand, subjective norms refer to individuals' perceptions of the expectations and intentions of significant others, who they believe have a crucial impact on their willingness to engage in the target behavior.

2.5.3 Theory of planned behavior

In 1985, Ajzen (1991) identified a crucial aspect of the Theory of Reasoned Action in the subsequent research. The original model, while effective in predicting individual behavior based on attitudes and subjective norms, overlooked the confidence support an individual might need when executing a behavior. Even when individuals develop positive behavioral attitudes and subjective norms, they might lack the confidence required to translate these intentions into action. In response, the original model was expanded and modified to better align with real-world scenarios, giving rise to the Theory of Planned Behavior (TPB) (Ajzen, 1991).

As depicted in Annex A (Figure A.2), this model builds upon the TRA by introducing the variable of perceived behavioral control. Perceived behavioral control refers to an individual's confidence in performing a particular behavior, influenced by facilitative conditions—both internal and external control factors such as personal abilities, characteristics, opportunities, and resources (Ajzen, 1991). When perceived facilitative conditions pose less resistance to an individual's behavior, their confidence in executing that behavior increases. Control beliefs serve as another influencing factor on perceived behavioral control; the stronger the control beliefs, the more enhanced an individual's perception of facilitative conditions, thereby amplifying the impact on behavioral intentions related to perceived behavioral control (Ajzen, 1991).

2.5.4 Technology acceptance model

Based on the Theory of Reasoned Behaviour, Davis (1989) proposed the Technology Acceptance Model was proposed, which is used to explore the factors that influence people's acceptance and adoption of new technologies, and to elucidate and predict users' behaviour in the process of technology adoption and use. This model serves to demonstrate the influencing factors determining people's acceptance and utilization of new technology, offering explanations and predictions for users' technological behaviors.

As illustrated in Annex A (figure A.3), the theory posits that an individual's intention and behavior in using technology depend on their perceived usefulness and ease of use of a specific technology (Portz et al., 2019). Davis (1989) asserted that the adoption of any technology is based on certain assumptions, with the key factors in the TAM being perceived ease of use and perceived usefulness. Perceived usefulness was defined as "the degree to which a person believes that using a particular system will enhance his or her job performance", while perceived ease of use is "the degree to which a person believes that using a particular system is effortless".

Both perceived usefulness and perceived ease of use exhibit positive correlations with "usage attitude". If users perceive technology as enhancing job performance or being easy to use, they are likely to provide positive evaluations and, conversely, negative evaluations if they believe otherwise. There is a positive correlation between "usage attitude" and "usage intention", meaning that the more favorable the user's attitude towards a particular technology, the higher the intention to use it. Furthermore, perceived usefulness directly influences "usage intention," subsequently leading to "usage behavior" (Davis, 1989).

This model has garnered extensive attention in the field of technology acceptance research and is deemed a "key model". In a comprehensive review of the application of the TAM in healthcare, Ammenwerth (2019) found that the model could predict 30-70% of the variability in usage intention.

The development of the Technology Acceptance Model has undergone numerous changes. In 2000, Venkatesh and Davis (2000) empirically showed that the variable of perceived usefulness has a relatively small direct effect on behavioural attitudes, however, there is a significant and direct strong correlation between it and willingness to use, and that the role of behavioural attitudes as a mediating variable is not significant in the framework of the study of technology adoption and use behaviours, leading to removing the "attitude" variable from the model.

Simultaneously, a new variable was introduced, aiming at social influences (such as those from colleagues or superiors) that compel end-users to positively evaluate and accept digital health technologies. This variable was termed Subjective Norm (SN).

Thus, the Technology Acceptance Model 2, as illustrated in Annex A (figure A.4) is expanded and improved on the original basic model by including the consideration of the role of social influences and cognitive tools on information reception behaviour, thus effectively compensating for the limitations and shortcomings of the original model. This improvement makes the technology acceptance model more scientifically rigorous, comprehensive, and detailed, and significantly enhances its explanatory power for related phenomena and its guiding value in practical application scenarios (Venkatesh & Davis, 2000).

2.5.5 Integration model of the technology acceptance model and the theory of planned behavior

In 1995, variables from the Technology Acceptance Model (TAM) were combined with those from the Theory of Planned Behavior (TPB) to propose the Integration Model of TAM and TPB, abbreviated as C-TAM-TPB (Taylor & Todd, 1995). Both the TAM and the TPB are extensions of the TRA. Still, they differ in emphasis, resulting in theoretical compatibility and complementarity (Chau & Hu, 2002).

As illustrated in Annex A (Figure A.5), Taylor and Todd identified factors influencing individual behavioral intentions, primarily encompassing subjective norm, perceived behavior control, behavioral attitude, perceived usefulness, and ease of use. In the C-TAM-TPB model, the perceived usefulness and ease of use from the TAM are considered important influencing factors on the attitude beliefs of the TPB. The TPB enhances the explanatory power of the TAM by introducing additional core variables related to technology acceptance.

This integration results in a more comprehensive model combining the strengths of the TAM and the TPB.

2.5.6 Motivational model

In 1992, the Motivational Model (MM) was introduced as a framework for studying the adoption and utilization of information technology (Davis et al., 1992). The MM elucidates that individual behavior and their acceptance and use of technology are concurrently influenced by intrinsic and extrinsic motivations (Taherdoost, 2018). Thus, the MM is employed to explore intrinsic motivations (effort expectancy, anxiety, and attitudes towards information technology) and extrinsic motivations (social influence and convenience) (Grani, 2023).

Davis (1989) identified perceived usefulness as an extrinsic motivation while perceived enjoyment as an intrinsic motivation. Research indicates that individuals' motivation to use computers in the workplace is primarily influenced by their perceptions of the computer's efficacy in enhancing job performance, followed by the level of enjoyment experienced during computer use.

Furthermore, a positive interactive relationship exists between perceived usefulness and enjoyment, signifying that as individuals perceive computer systems to be more useful, the impact of perceived enjoyment on their intention to use becomes more pronounced.

2.5.7 Model of personal computer utilization

In 1991, Thompson and colleagues, building upon the theory of human behavior proposed by Triandis, adjusted Triandis's model (1971, 1980) in the context of Information Systems/Information Technology (IS/IT). This adaptation led to the development of the Model of Personal Computer Utilization (MPCU), designed to evaluate the usage patterns of personal computers (Thompson et al., 1991).

As illustrated in Annex A (Figure A.6), the MPCU is specifically tailored to assess the direct influences of emotions, facilitating conditions, long-term consequences of use, perceived outcomes, social influences, complexity, and job suitability on individual computer usage behavior. Since the MPCU model primarily focuses on actual behaviors when using computers, behavioral intentions were excluded from the proposed model (Taherdoost, 2018).

2.5.8 Innovation diffusion theory

In 1962, Rogers (2003) first proposed the Innovation Diffusion Theory (IDT) in his book "Diffusion of Innovations", aiming to explore how innovative concepts spread and are accepted by individuals.

After observing various influencing factors in the process of innovation diffusion, Rogers (2003) summarized the basic patterns of innovation diffusion: the spread of innovation in a social system often exhibits a growth trend resembling an S-shaped curve over time. As illustrated in Annex A (Figure A.7), during the introduction phase, people have limited knowledge and low acceptance of innovative concepts, resulting in a relatively flat diffusion curve and a slow diffusion process. Innovators and leaders are the first to adopt innovation during this stage. Upon reaching the adoption phase, the innovation accelerates its diffusion, and most societies adopt it. As the societal adoption of innovation gradually saturates, entering the maturity phase, the diffusion speed decreases, and conservatives adopt the innovation during this stage.

2.5.9 Social cognitive theory

In the 1980s, Bandura (1986) introduced the Social Cognitive Theory (SCT), which has become one of the classic theories in health promotion and social psychology. An in-depth study of the interdependence was conducted between individuals, environments, and behaviors. The SCT considers personal, environmental, and behavioral factors as three mutually independent yet interacting elements, forming the core of the triadic reciprocal determinism.

In the SCT, individual factors encompass one's personality, cognition, and demographic characteristics. Behavioral factors include using, performing, and adopting a particular technology. Environmental factors encompass both physical and social considerations (Taherdoost, 2018). The theory posits that (1) individuals play a dominant role in behavior, with cognitive processes guiding behavior and feedback from behavioral outcomes leading to self-regulation; (2) changes in the environment affect behavior, while behavior itself is constrained by the environment; (3) the environment influences individual cognition, and, conversely, individual cognition affects the surrounding environment. This illustrates the mutual influence and determination among individuals, behavior, and the environment (Bandura, 2018).

2.5.10 Unified theory of acceptance and use of technology

In 2003, Venkatesh et al. (2003) conducted a systematic and rigorous analysis of eight important models in the user acceptance field, namely the Theory of Reasoned Action (TRA), Technology Acceptance Model and its extended version (TAM, TAM2), Model of PC Utilization (MPCU), Combined TAM-TPB model (C-TAM-TPB), Social Cognitive Theory (SCT), Motivational Model (MM), Theory of Planned Behavior (TPB) and Innovation Diffusion Theory (IDT). They extracted and adjusted key factors from each model to propose the Unified Theory of Acceptance and Use of Technology (UTAUT). This theory aims to assess the likelihood of new technology success and understand the driving factors for acceptance.

As illustrated in Annex A (Figure A.8), UTAUT includes four core determinants of intention and use, as well as up to four moderating factors. The theory considers Performance Expectancy (PE), Effort Expectancy (EE), Social Influence (SI), and Facilitating Conditions (FC) as direct determinants of Behavioral intention (BI). Specifically, Performance Expectancy is the extent to which an individual believes that using the system will help progress in their job performance, corresponding to the perceived usefulness in the TAM. Effort Expectancy is the perceived ease of use associated with system usage, analogous to the perceived ease of use in the TAM (Ammenwerth, 2019).

Social Influence is the degree to which important individuals believe the person should use the new system. Facilitating Conditions are defined as the extent to which individuals believe that organizational and technical infrastructure support system usage (Ammenwerth, 2019). Additionally, the model incorporates education, age, gender, and experience as control variables to understand the impact of selected variables on the target variable (H. Liu et al., 2016).

2.5.11 Technology acceptance models used in public health research

The research on UTAUT in the field of public health mainly focuses on observing people's acceptance behavior and influencing factors of some new digital health technology applications. For example, Cimperman et al. (2016) analysed the acceptance behaviour of older people towards home telemedicine services. Jacob et al. (2020) paid attention to the factors influencing the adoption of mHealth tools by clinicians. Q. Zhang et al. (2023) discuss which factors drive the adoption of online health communities.

We similarly note some examples of practises conducted in China. Y. Liu et al. (2022) examined Chinese patients' attitudes towards mobile health services and the influencing factors. J. Liu et al. (2023) explored the role of habit and trust in older people's acceptance of mhealth. W. Li et al. (2023) investigated the factors influencing the acceptance and use of remote health management services among older urban residents in China.

Chapter 3: Investigation – Research Design and Methods

3.1 Research introduction

Based on the literature review, we designed three studies with successive qualitative and quantitative research.

In the first study, we conducted a meta-analysis and a documental study based on the grounded theory to understand from the literature of the current state of digital health technologies adoption in older adults with chronic diseases and the possible influencing factors affecting the use of digital health technologies in older adults with chronic diseases.

In the second study, we selected a hospital and some patients with chronic diseases to conduct focus group interviews to understand the perceptions and use of digital health technologies among older chronic patients in the real world.

In the third study, based on the extended UTAUT model, combined with the KAP theory, and drawing on international questionnaires (that were used and validated in previous studies), we propose a new theoretical-conceptual model and developed a questionnaire – according to the factors or latent variables in the proposed model, and their causal relationships. In sequence, we drew larger samples from different levels of healthcare organisations in Shanghai to conduct surveys, using the questionnaire, to validate the new model and identify facilitating and hindering factors affecting the acceptance and use of digital health technologies by the elderly chronic patient population, and to propose strategies to promote the adoption of digital health applications by elderly patients with chronic diseases.

3.2 Methodological approach

The current research is conducted in the context of the rapid development of digital health strategies on a global scale. As a developing country, China is rapidly advancing its digital health strategy while the issues of aging and chronic diseases are becoming increasingly prominent, making it a very suitable and important research sample. Although there is much literature worldwide that suggests some research results in this field, there is relatively little data on developing countries like China.

In view of this, we plan to use a literature review to understand the utilization of digital health for elderly chronic patients in countries around the world, including China, to identify problems and challenges and to obtain more evidence in the real world. By selecting and using appropriate theoretical models, we will study the factors that affect the acceptance and use of digital health technology by elderly chronic patients.

A mixed research method consisting of qualitative and quantitative studies will be used in the research, and samples will also be selected from representative medical institutions in the economically developed city of Shanghai, China. During the research process, a literature review was conducted to clarify the direction and scope of the study. Based on this, a portion of patient representatives were selected for focus group discussions to refine the questions further and find answers. The introduction of theoretical models will facilitate the exploration of various influencing factors related to the use of digital health technology. Combined with previous research results, we may then better explain the mechanism of influencing factor formation, and thus obtain valuable improvement strategies.

The research design process is illustrated in detail in Annex B. Our scientific project is developed according to a research plan – and it is structured around the research design process, conducted between September 2021 and October 2024, with a specific research calendar – as shown in Annex C.

3.3 Quality control

3.3.1 Study 1 – documental or bibliographical

3.3.1.1 Survey preparation phase

Two professional researchers independently completed the preliminary literature screening, excluding those that did not meet the inclusion criteria. If there were disagreements in the screening results, a third senior researcher made a comprehensive judgment.

3.3.1.2 Data compilation phase

For content with controversy, it will be discussed and determined with two other professional researchers. Secondly, axial coding and selective coding are jointly discussed by the project team experts. By exploring the intrinsic logical relationships between different initial categories, the main categories are induced and summarized. Through systematic induction and analysis of the main categories, highly correlated core categories are further condensed, ultimately forming a three-level coding system. Finally, to comply with the principle of empirical saturation of qualitative research samples, saturation testing is required.

This study used a simple random sampling method to code and analyze at least 75% of the textual data, and after forming a stable theoretical model, continued to code the remaining 25% of the textual data. If no new themes appear, it means that the qualitative analysis has reached saturation state.

3.3.2 Study 2 – qualitative

3.3.2.1 Survey preparation phase

A primary researcher and three assistants carried out the focus group discussions at Xinhua Hospital. To guide these discussions, a semi-structured interview outline was developed based on the results of previous literature research (Portz et al., 2019; Townsend et al., 2015; Wildenbos et al., 2019). The interview outline is described as follow.

The focus group discussions started with some general perceptions. The researchers introduce the topic “How about the understanding of the situation of digital health applications in Shanghai?” by asking the following questions to participants: (1) What do you think about digital health? (2) What digital health applications do you know? (3) How do you feel being accompanied, or monitored through digital health applications? (4) What are the similarities and differences between digital health and the traditional healthcare model? (Advantages vs. disadvantages).

Then, the investigators introduced three topics in order to understand respondents' needs for digital health apps, namely “Digital health applications and the health needs of elderly patients with chronic diseases”; “Expectations, preferences, and attitudes of elderly patients with chronic diseases towards digital health applications”; “Knowledge and ability of elderly patients with chronic diseases to use digital health applications”. Specifically, the first topic encompasses the following questions: (1) Which digital health applications do you use often? (2) On what occasions do/will you use digital health applications? (3) Would you use digital health applications when you need healthcare? Why? The second topic encompasses the following questions: What are your opinions, attitudes, or expectations towards digital health applications and related technologies? Why? The third topic encompasses the following questions: What do you think about your knowledge and skills in digital health applications and related technologies? What do you suggest?

Investigators similarly focused on the use of digital health technology, therefore, the questions below were addressed: (1) What digital health applications and related technologies have you ever used? What’s your opinion of them? Why? (2) What do you know and think about digital health services (e-pay, e-appointment, etc.)? (3) What digital health applications do you want to use to replace traditional healthcare models in the future? (4) Do you have the knowledge and skills to use the applications and technologies? (5) Do you need any help when using these applications and techniques? Can you get help in time? (6) Which digital health applications do you prefer? Why?

Then comes the section on facilitators and barriers. For facilitators, two topics are covered: (1) Which digital health applications are preferred by elderly people with chronic diseases? (2) What are the characteristics of these digital health applications? Specific questions included: (1) Which digital health applications would you most like to use? Why? (2) Do you have any digital health applications that you are eager to learn to use? Why? (3) Which digital health applications make you feel more convenient, safe, or efficient in the process of diagnosis, treatment, or health management? (4) What is your biggest driving force in using digital health applications? (Internal or external, please describe it specifically) (5) Are you willing to use more digital health applications in the future? Why? (6) What can help you use digital health applications more?

For barriers, two topics are covered: (1) Which digital health applications are not well accepted by elderly patients with chronic diseases? (2) What are the factors that affect the use of digital health applications by elderly patients with chronic diseases? Specific questions included: (1) What difficulties have you encountered in using digital health applications? (2) What digital health applications are most difficult for you to use? Why? (3) What kind of help do you need when using digital health applications? And who can help you? (4) What factors or concerns limit your use of digital health applications? (5) For you, what factors restrict the use of digital health applications? (Internal or external, please specify).

In the "Scenarios" section, two topics are presented: (1) Scenarios related to digital health applications for elderly patients with chronic diseases? (2) How about the use of digital health applications in these scenarios? Specific questions are listed below: (1) What scenarios do you use digital health applications in? (hospital, community, family, or others) (2) What are your suggestions for using digital health applications in these scenarios? Why? More specifically, the following scenarios are involved: Outpatient department, inpatient department, emergency department, community healthcare facilities and home, by asking: (1) What is your experience of using digital health applications in these scenarios? (2) Do you think that in these scenarios, the traditional healthcare model is insufficient and needs to be supplemented or replaced by digital health applications? (3) What are the scenarios of digital health applications that you are most willing to accept? Why?

At the end of the focus group, the investigator asked respondents weather there is any other ideas for this topic. Finally, the investigator learnt about the respondents by asking their general opinion when it comes to the help provided by digital health in medical treatment and health management.

3.3.2.2 On-site survey phase

Conducting the focus group discussions involved creating a conducive environment. The main researcher and assistants organized discussions following the interview outline, keeping the conversations focused on the research topic. Participants were informed that only one person could speak at a time to prevent confusion. The researchers actively encouraged all participants to contribute to the discussion without passing judgment on their opinions.

Non-verbal cues, such as facial expressions, were closely observed throughout the discussions. Important insights and observations were recorded in interview memos for later analysis. In cases where participants provided consent, the entire investigation process was recorded on-site through audio-visual means. This recording facilitated subsequent transcription into detailed interview text data, allowing for a more in-depth exploration of the collected information.

3.3.2.3 Data compilation phase

The audio-visual materials recorded during the focus group discussions were systematically reviewed. Two researchers repeatedly examined the recordings to create a transcript. This transcript was a verbatim account, capturing participants' expressions and language without modification. To ensure privacy, a desensitization process was applied, where sensitive information such as names and locations was replaced with alphanumeric combinations. This desensitized interview text was then used for subsequent coding and analysis, balancing detailed investigation, and maintaining participants' privacy and security.

3.3.3 Study 3 – quantitative

3.3.3.1 Survey preparation phase

During the preparation phase of the investigation, several key steps were undertaken to ensure the smooth and ethical conduct of the study. Firstly, given that the research targeted elderly chronic patients seeking treatment in hospitals, it was recognized that the survey might involve sensitive information related to patient privacy. Consequently, before initiating the study, the research plan and ethical review document were submitted to the Medical Research

Management Committee and Ethics Committee of Xinhua Hospital, the institution with which the researchers are affiliated.

The study obtained official approval with the ethics approval number XHEC-C-2022-110-1, as documented in Annex D. To adhere to ethical standards, an informed consent form was meticulously developed for the study. This document outlined the key aspects of the research, and participants were required to provide their consent before engaging in the questionnaire survey and focus group discussions.

For the on-site questionnaire surveys, a team of 8 volunteers was recruited to participate. These volunteers underwent thorough training in survey methods to ensure their familiarity with the study's main objectives and questionnaire content and to cultivate language fluency. The training emphasized the importance of maintaining an objective and neutral attitude during interactions with participants, avoiding any form of prompting or inducement, and ensuring a faithful representation of participants' intentions.

3.3.3.2 On-site survey phase

Initiating the on-site questionnaire surveys required meticulous planning. The researchers proactively coordinated with the responsible personnel in various medical units to arrange suitable times and locations. This ensured no repetition of questions to the same patient across different sampling units. Rigorous control measures were implemented during the on-site surveys, with dedicated personnel overseeing the process to prevent undue influence or bias. Each participant was allotted a specific time frame to complete the questionnaire, and the on-site team ensured that each question-and-answer session adhered to a reasonable duration, minimizing potential Hawthorne effects. Through real-time monitoring, the research team-maintained control over the quality of the questionnaire.

3.3.3.3 Data compilation phase

The meticulous compilation of data was crucial for maintaining the integrity of the study. Every questionnaire obtained during the survey underwent a thorough verification process. Two researchers conducted a back-to-back review of each questionnaire to identify issues such as attention problems, contradictions, logical errors, omissions, incorrect fillings, overly brief completion times, or instances of simple and repeated answer options. Any questionnaire found to have such issues was considered ineligible and excluded from the analysis. Eligible questionnaires were systematically numbered.

3.4 Theoretical framework for the quantitative study

Research in the field of technology acceptance has yielded many mature theoretical models. Researchers face the challenge of choosing among numerous models, and selecting one often leads to the oversight of contributions from other models. Adopting the Unified Theory of Acceptance and Use of Technology (UTAUT), which integrates eight theoretical models, mitigates this issue to some extent (Venkatesh et al., 2003). Venkatesh et al. (2003) found that the UTAUT exhibits explanatory power as high as 70% for the intention to use technology, surpassing many foundational models.

Despite the widespread use of the UTAUT as a theoretical foundation for predicting technology acceptance and use, results in the medical and health fields vary (Ammenwerth, 2019). Ward (2013) indicated that, in many cases, the original UTAUT fails to demonstrate strong predictive ability for the acceptance of health technologies. Additionally, in a literature review of factors influencing the use of digital health technology in elderly chronic patients, it was found that elderly chronic patients generally hold positive attitudes towards adopting digital health technology.

This implies a predisposition among elderly chronic patients to engage in "usage behaviour". However, in different contextual scenarios, numerous factors, including user experience, interpersonal support, awareness of capabilities, technological factors, sense of security, and service functional needs, may significantly influence the "intention to use" among elderly chronic patients. We found that these factors have a certain overlap with the moderating factors in the Unified Theory of Acceptance and Use of Technology.

Therefore, it is necessary to develop the UTAUT model further, re-examine the relationships and interactions between variables, and particularly, draw insights from relevant theories in the health domain to better guide the application of digital health technology in elderly chronic patients.

The Knowledge, Attitude, and Practice Model (KAP) is one of the most used models for explaining how individual knowledge and beliefs influence health behaviour change (Glomsås et al., 2020) and is one of the most classic theories in health communication.

In this study we propose a new conceptual model that integrates the classic Unified Theory of Acceptance and Use of Technology (UTAUT) resulting in the KAP-UTAUT extended model – to explain the acceptance and use of digital health technologies by elderly chronic disease patients.

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Chapter 4: Literature Review (Part Two - Documental Study: Descriptive and Qualitative Analysis)

4.1 Presentation of study 1 – documental or bibliographical

In this study, we conducted a systematic review of the status of the use of digital health technologies in older adults with chronic diseases by searching the literature published in Pubmed, Embase, and Cochrane Library from 2000 to 2022. We carried out a documental study of 31 included papers based on the grounded theory and with the help of NVivo software. From the literature, we can thus understand the current state of digital health technologies use in older adults with chronic diseases and the possible influencing factors that affect the use of digital health technologies by them.

4.2 Objectives

As a completion of the literature review, we developed this bibliographical or documental study to have a comprehensive understanding of what has been done in the field of digital health applications for elderly patients with chronic diseases and determine the pain points in this scientific field. So, the main objective is:

(1) Verify how the service strategies and digital health technologies for elderly individuals with chronic diseases have been approached in scientific research (in the period 2014-2022). (Research **Objective 1**)

4.3 Methodology

4.3.1 Literature screening – inclusion and exclusion criteria

Figure 4.1 shows the flowchart of literature inclusion in this study – according to the inclusion and exclusion criteria, we selected and adopted 31 studies.

Inclusion criteria in papers' selection:

(1) Study design types are quantitative, qualitative, or mixed research;

(2) Patients age are 60 years or older (including all genders, regions, and races);

(3) Diagnosed with one or more chronic diseases;

(4) The research topic is about the motivation, obstacles, scenarios, and needs of digital health technology use.

Exclusion criteria:

(1) Repetitive literature;

(2) Digital health intervention technology not targeted at elderly people aged 60 and above or chronic diseases;

(3) Study deviating from the research topic;

(4) Review-type paper;

(5) Grey literature, narrative reviews, conference papers, books, letters, and other literature with no full text available.

This systematic review strictly adheres to the Preferred Reporting Items for Systematic Review and Meta-Analyses (PRISMA) method and formulates research questions accordingly (Moher et al., 2015). We conducted a systematic search of the PubMed, Embase, and Cochrane Library databases from January 1, 2000 to August 22, 2022, using search terms related to the use and acceptance of digital health technology among elderly patients with chronic diseases. There are over 20 medical literature databases, and these three databases are commonly used medical literature databases, all of which are free. In addition, to ensure that the literature ultimately included in the review study is more comprehensive, this study also conducted additional searches on the Web of Science database, Scopus database, and Google Scholar to search for relevant studies on the acceptance and use of digital health technology by elderly chronic disease patients.

To determine the search categories, two researchers specializing in social medicine and health management jointly developed the search strategy. The search terms "digital health," "elderly," and "chronic disease" were used to identify articles relevant to the research question. The search term "digital health" was used because it is the intervention method of interest in the research question, "elderly" was used because the study population of interest is elderly individuals, and "chronic disease" was used because the purpose of the study is to improve chronic disease management using digital health technology. Specifically, we used the medical subject heading (MeSH) search function in the Cochrane Library to determine relevant MeSH terms and synonyms for more accurate literature searches. MeSH terms are subject headings compiled by the US National Library of Medicine, which use a tree structure to classify all research literature for indexing purposes. We used Boolean operators (e.g., AND, OR, NOT) to combine MeSH terms and synonyms for literature search. For detailed search strategies used in each database. Additionally, to propose a theoretical model for this research and identify key factors affecting the acceptance and use of digital health technology, we searched for classic theoretical models applied in the digital health technology field in the PubMed literature database. The specific search formula is listed in Annex E.

A total of 299 scientific papers or studies were retrieved from Pubmed, 85 from Embase, and 69 from Cochrane Library – in a total of 453. After removing 93 duplicate studies, a total of 360 studies were screened based on their titles and Abstracts. According to inclusion criteria, we excluded 306 studies for the following reasons: review studies, studies with participants aged less than 60 years, studies unrelated to digital health, studies focused on disease management with digital health applications but not related to chronic diseases, studies without any literature on factors influencing the use of digital health technologies in their results and conclusions, and other types of publications such as conference papers, commentaries, and books.

We then conducted a review of 54 papers/studies. We excluded 23 studies for the following reasons: studies that did not make digital health technology the main intervention were excluded, studies that only described research design but did not conduct practice were excluded, studies that focused on cross-sectional surveys but did not involve factors influencing the use of digital health technologies were excluded, studies that focused on digital health technology itself but were not closely related to chronic disease management were excluded, and studies that were not available in full-text were excluded.

In addition, after the completion of literature research, we conducted additional searches on the Web of Science database, Scopus database, and Google Scholar. The search results are as follows: A total of 18 references were obtained from the Web of Science database. After comparing the literature databases, 14 of them were duplicated, and 4 of them focused on the design and validation of digital health platforms, which did not meet the inclusion and exclusion criteria. A supplementary search of the Scopus database resulted in 172 articles. Using the database filtering function, the focus was on the "Medicine" research field and the article type was "Article". Other relevant literature in the computer and engineering fields, as well as reviews, reviews, protocols, and other studies, were excluded. A total of 77 articles were obtained. By comparing the literature databases, 41 articles were duplicated, and 36 articles did not meet the inclusion and exclusion criteria due to their focus on the clinical intervention effects of digital health technology, not on elderly chronic disease patients, not using digital health technology as the main intervention measure, and focusing on the design and validation of digital health platforms. The researchers plan to conduct supplementary searches through

Google Scholar. As Google Scholar serves as a network search engine for literature search, it only has simple search channels such as title, author, and publisher, and does not have the function of topic keyword search. Therefore, it is not possible to accurately search for literature related to the application of digital health technology in elderly chronic disease patients through standardized and standardized search methods. Based on the above literature screening results, a total of 31 articles met our inclusion criteria based on the Pubmed database, Embase database, and Cochrane Library database. No new research articles were found through supplementary searches of the Web of Science database and Scopus database. Therefore, a total of 31 articles were ultimately included in the review study.

By comparing the research databases, 41 documents were duplicated, and 36 documents did not meet the inclusion and exclusion criteria because they focused on the clinical intervention effect of digital health technology, did not focus on elderly patients with chronic diseases, did not use digital health technology as the main intervention, and focused on the design and validation of digital health platforms. The results of the additional literature search showed that the final 31 papers included in this study were well represented.

4.3.2 Literature collation

Initial literature screening was completed independently by two professional researchers to exclude papers/studies that did not meet the inclusion criteria, and a third senior researcher made a combined judgement in the event of a disagreement in the screening results. All literature was managed using NoteExpress software.

The descriptive data of all the included papers were extracted and integrated, and relevant charts were drawn to present the extracted descriptive data visually, which included title, author, country, publication date, publication journal, impact factor, keywords, type of study, study perspective, type of chronic disease covered, and sample size.

4.3.3 Papers analysis

4.3.3.1 Nvivo

Developed by Lumivero (formerly QSR International), Nvivo is a professional-grade software program for qualitative research, primarily used to analyse unstructured text, including but not limited to interviews, focus groups, and journal articles (Dhakal, 2022). NVivo allow us to do content analysis or textual analysis, to classify, categorize and find possible core concepts or clusters of text, to be further analyzed, compared, and interpreted.

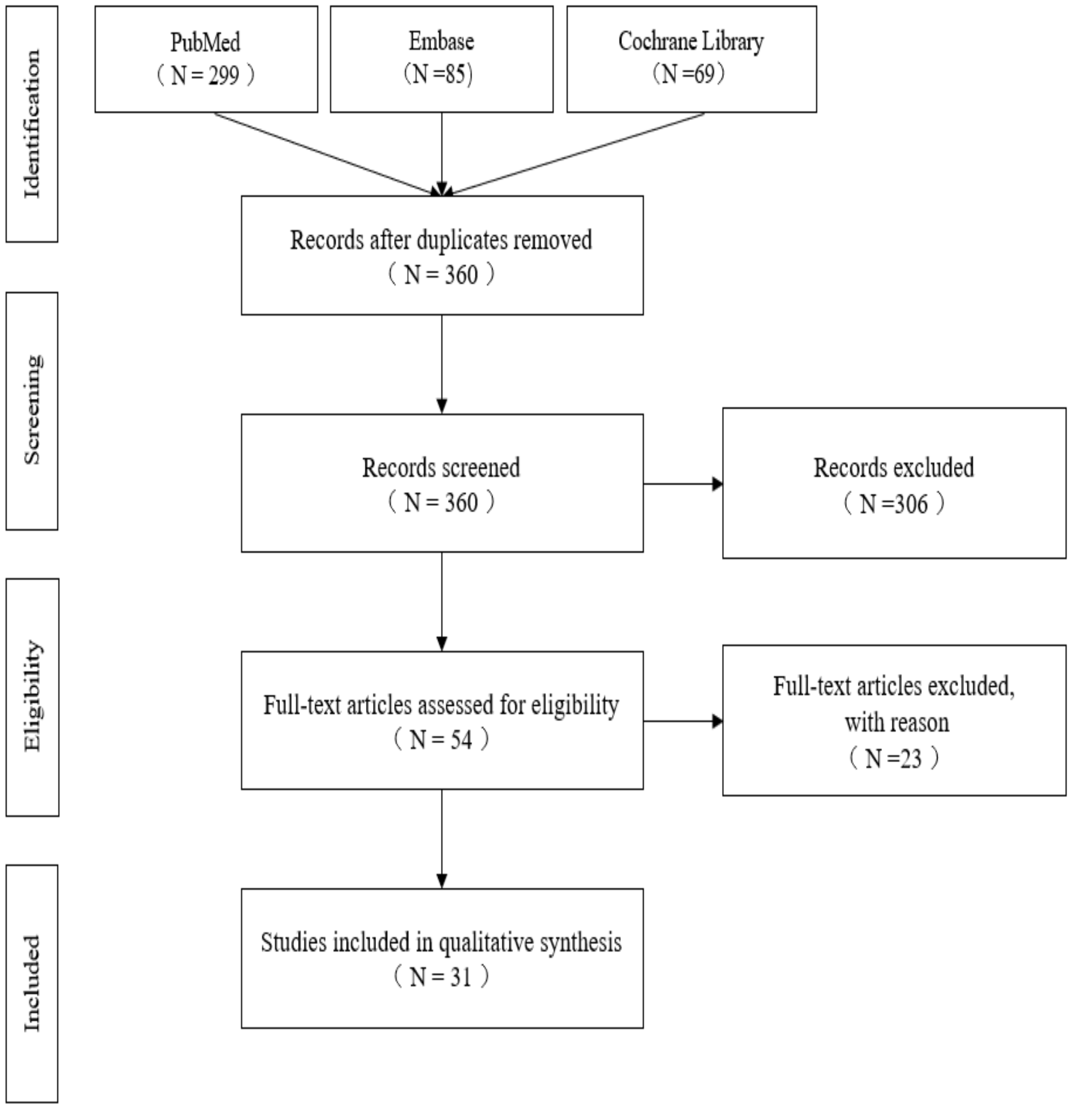

Figure 4.1 Strategies and processes for selecting literatures in the documental study

All literature materials (31 full articles) are imported into NVivo 12 software to form an original file. Two professional researchers are responsible for open coding, and each article is read and analyzed sentence by sentence and paragraph by paragraph. The original sentences are abstracted, and nodes are established to extract initial concepts as comprehensively as possible. Different concepts are summarized and reorganized into initial categories. Controversial content will be discussed and determined with two other professional researchers.

Secondly, the research group experts jointly discuss the main axis encoding and selective encoding. The main categories are summarized by exploring the inherent logical relationships between (different) initial categories. The highly correlated core categories are further condensed through systematic induction and analysis of the main categories, ultimately forming a three-level encoding system. Finally, saturation testing is required to comply with the principle of qualitative research sample experience.

This study used a simple random sampling method to perform coding analysis on at least 75% of the text data. After forming a stable theoretical model, the remaining 25% of the text data was further coded. If no new topics appear, it has reached saturation.

4.3.3.2 About grounded theory

Grounded theory was employed to analyze the included data, extracted from the articles.

In the 1960s, American sociologists Glaser and Strauss jointly proposed Grounded Theory in their study of hospital organisation and end-of-life care processes. Grounded Theory is an important method of theory construction in qualitative research (Charmaz & Thornberg, 2021).

Grounded theory comprises three main steps: open coding, axial coding, and selective coding. Core concepts and categories are constructed through continuous refinement of coded raw data, and ongoing comparisons are made until theoretical saturation is achieved. Open coding involves reading and coding text data sentence by sentence to comprehensively extract initial concepts and organizing different concepts into initial categories. Axial coding refines, adjusts, and classifies the categories obtained from open coding, merging semantically similar or related components. Selective coding involves deep exploration of relationships between all categories, ultimately constructing the substantive theoretical framework (Turner & Astin, 2021).

Using grounded theory, as the name suggests, the most crucial point is to emphasise that the theory must be grounded in the data, and the researcher does not make preconceived hypothetical inferences about the object of study but rather starts directly from the data itself (Charmaz & Thornberg, 2021). It is the process of distilling concepts and categories and making associations from raw data. Grounded theory points out that only theory rooted in raw data can reflect the essential characteristics of the object of study and have explanatory and predictive power.

4.4 Results

4.4.1 Overview of digital health applications in the literature

Figure 4.2 presents the publication timeline of the 31 studies included in this review, published between 2014 and 2022, with the highest number of studies (8) included in 2020. Figure 4.3 presents the geographical distribution of the studies, with 18 studies (58.06%) originating from Europe, eight studies (25.81%) from North America, and five studies (16.13%) from Asia. The country with the highest number of published studies was the Netherlands (6), followed by Canada (5), and then Sweden, Germany, the United Kingdom, and China (3 each). In terms of study design, there were a total of seven quantitative studies (22.58%), of which three utilized a cross-sectional survey approach, two utilized a randomized controlled trial approach, one utilized a cohort study approach, and one was a nationwide data survey. There were 19 qualitative studies (61.29%), of which 13 utilized a semi-structured interview approach, 6 utilized a focus group interview approach, and two utilized a think-aloud method. There were four mixed-method studies (12.90%) and one conceptual experimental study (3.23%).

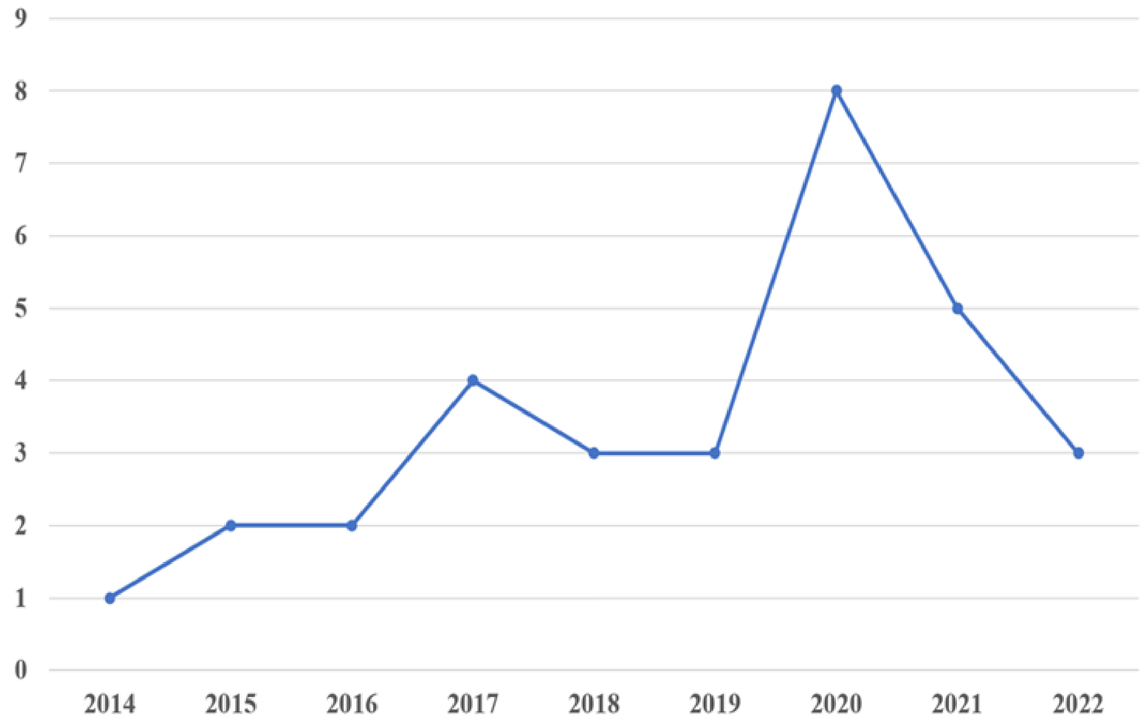

Figure 4.2 Studies published in 2014-2022

Figure 4.3 Studies published in different countries

According to the papers analysis, we found 25 studies (80.65%) based on the perspective of elderly chronic disease patients, three studies based on the perspective of healthcare service providers, and three studies covering both perspectives. Among the six studies that included the perspective of healthcare service providers, three recruited respiratory doctors and nurses to discuss the application of digital health technology in COPD management (Alwashmi et al., 2020; Alwashmi et al., 2019; Jiang et al., 2022), one study recruited community health workers to discuss the views on using digital health technology to prevent hospitalization of elderly people living at home (Gjestsen et al., 2020), one recruited pharmacists, general practitioners, internists, psychiatrists, and geriatricians to discuss the views on using interprofessional communication digital health technology to optimize medication management for elderly immigrants with chronic diseases (Bird et al., 2022), and one recruited rheumatologists and nurses to discuss the impact of digital health technology on the doctor-patient relationship (Townsend et al., 2015).

Table 4.1 presents the main characteristics of the included literature – according to the selected papers/studies – regarding the publication time, country of origin, study type, sample size, chronic disease types covered, research perspective, and types of digital health technology.

Table 4.1 Characteristics of the included papers/studies

Researcher	Country	Research Type	Sample Size	Disease	Perspective	Digital Health Technology Type
Wenbo He, 2022	USA	Quantitative Study	7060	Chronic Disease	Patients	Internet Health Consulting Services, Online Pharmacy, Online Clinic Appointments, Doctor-Patient Online Communication
Andreas Andreou, 2022	UK	Mixed Methods Study	7	Asthma, COPD	Patients	Patient Mutual Aid Platform, Family Mutual Aid Platform
Yuyu Jiang, 2022	China	Qualitative Study	52	COPD	Medical Staff and Patients	Online Health Education, Health Tracking Diaries, Doctor-Patient Online Communication
de Batlle Jordi, 2021	Spain	Quantitative Study	87	COPD, Heart Failure	Patients	Health Tracking Diaries, Doctor-Patient Online Communication, Physiological Data Monitoring Tools, Sensors, Family Mutual Aid Platform
Marian Z M Hurmuz, 2021	Netherlands	Mixed Methods Study	51	Diabetes, Chronic Pain	Patients	Online Health Education, Virtual Health Coach
Meshari F. Alwashmi, 2021	Canada	Qualitative Study	40	COPD	Medical Staff and Patients	Online Health Education, Health Tracking Diaries, Family Mutual Aid Platform, Disease Self-Diagnostic Assessment
Martha Therese Gjestsen, 2021	Norway	Qualitative Study	17	Chronic Disease	Medical Staff	Health Tracking Diaries, Remote Video, Medication Use Reminder, Sensors, Home Alarm System
Julie Doyle, 2021	Ireland, Belgium	Quantitative Study	120	Diabetes, COPD, Congestive Heart Failure, and Chronic Heart Disease	Patients	Physiological Data Monitoring Tools, Sensors, Online Health Education, Health Tracking Diaries, Doctor-Patient Interactive Platform, Disease Self-Diagnostic Assessment

Rona Bird,2020	Germany	Qualitative Study	11	Chronic Disease	Medical Staff	Patient Medication Management
Meshari F Alwashmi, 2020	Canada	Mixed Methods Study	81	COPD	Patients	mHealth
Emmelie Barenfeld,2020	Sweden	Qualitative Study	12	COPD, Heart Failure	Patients	Smart Wearable Devices, Doctor-Patient Online Communication, Disease Information Search, Online Health Education, Health Tracking Diaries, Disease Self-Diagnostic Assessment
J Hu,2020	China	Quantitative Study	204	Parkinson's Disease	Patients	Patients Disease Information Search, Doctor-Patient Online Communication, Medication Advice, Health Tracking Diaries, Online Health Education
Johannes William Vergouw,2020	Netherlands	Qualitative Study	19	Chronic Disease	Patients	Internet Health Consulting Services, Online Report Query, Online Clinic Appointments, Online Pharmacy, Online Access to Medical Records
Maximilian Herrmann,2020	Germany	Qualitative Study	20	Stroke	Patients	Medication Use Reminders, Online Health Education, Ingestible Sensors, Healthcare Robots
Mei-Chen KUO,2020	China	Qualitative Study	11	Metabolism-related chronic diseases	Patients	Health tracking diaries, Online communication between doctors and patients, Disease information inquiry
Sara Lundell,2020	Sweden	Qualitative Study	13	COPD	Patients	Remote disease monitoring system
Meshari F Alwashmi, 2019	Canada	Qualitative Study	30	COPD	Medical Staff	mHealth
Veronica Milos Nymberg,2019	Sweden	Qualitative Study	15	Hypertension, Diabetes, COPD	Patients	eHealth
Jennifer Dickman	USA	Qualitative Study	24	Chronic diseases	Patients	Email, Online report inquiries, Online

Portz, 2019						pharmacy purchases
Heejung Kim, 2018	South Korea	Mixed Methods Study	25	Cardiovascular disease, Diabetes, Hypertension and Cerebrovascular diseases	Patients	Disease information inquiry, Physiological data monitoring tools, Health tracking diaries, Online interactive games, Doctor-patient interaction platform
Tessa van Middelaar, 2018	Netherlands	Qualitative Study	20	Diabetes, Cerebrovascular diseases	Patients	Online health education, Health tracking diaries, Online communication between doctors and patients, Remote medical video conferencing
G.A. Wildenbos, 2018	Netherlands	Qualitative Study	18	Heart failure, COPD	Patients	Health tracking diaries, Online outpatient appointment booking
Eboni G Price-Haywood, 2017	USA	Quantitative Study	247	Hypertension, Diabetes	Patients	Health tracking diaries, Internet health consulting services
Monika Urban, 2017	Germany	Qualitative Study	27	Chronic diseases	Patients	Wearable devices, Home health monitoring system
Simon Bourne, 2017	UK	Quantitative Study	88	COPD	Patients	Online classroom training, Health tracking diaries, Online communication between doctors and patients
Rakibul Hoque, 2017	Bangladesh	Quantitative Study	300	Chronic diseases	Patients	mHealth
Sarah Pludwinski, 2016	Canada	Qualitative Study	11	Diabetes	Patients	Physiological data monitoring tools, Health tracking diaries, Online health coach
Martine W. J. Huygens, 2016	Netherlands	Qualitative Study	30	Diabetes, COPD, Cardiovascular diseases	Patients	Physiological data monitoring tools, Virtual health coaches, Remote video conferencing, Doctor-patient interaction platform
Anne Townsend, 2015	Canada	Qualitative Study	32	Arthritis	Medical Staff and Patients	Healthcare professionals, Patients, Internet health

						consulting services
Maxine Hardinge,2015	UK	Quantitative Study	18	COPD	Patients	Medication use reminders, Physiological data monitoring tools, Home alarm systems
J. Hofstede,2014	Netherlands	Qualitative Study	400	Asthma, COPD	Patients	Internet health consulting services, Online pharmacy purchases, Online outpatient appointment booking, Online report inquiries

Among the 31 papers/studies included, seven (22.58%) did not specify the type of chronic disease, while 24 studies (77.42%) provided detailed descriptions of the chronic disease types. Among them, eleven studies (35.48%) focused on a single chronic disease, while 15 (41.94%) focused on multiple chronic diseases.

Of these, 15 (48.39%) recruited patients with chronic obstructive pulmonary disease (COPD), eight studies (25.81%) recruited patients with type 2 diabetes, four (12.90%) recruited patients with heart failure, three (9.68%) recruited patients with hypertension, and two (6.45%) recruited patients with cerebrovascular disease. The remaining six studies (19.35%) recruited patients with multiple chronic diseases, including asthma, chronic pain, heart disease, stroke, Parkinson's syndrome, and chronic arthritis. The 31 studies included 9090 participants, namely 125 healthcare providers and 8965 elderly patients with chronic diseases. One nationwide survey in the United States included 7060 elderly patients with chronic diseases, of whom there were significantly more female patients than male patients, and the age distribution of most patients was between 60 and 70 years old.

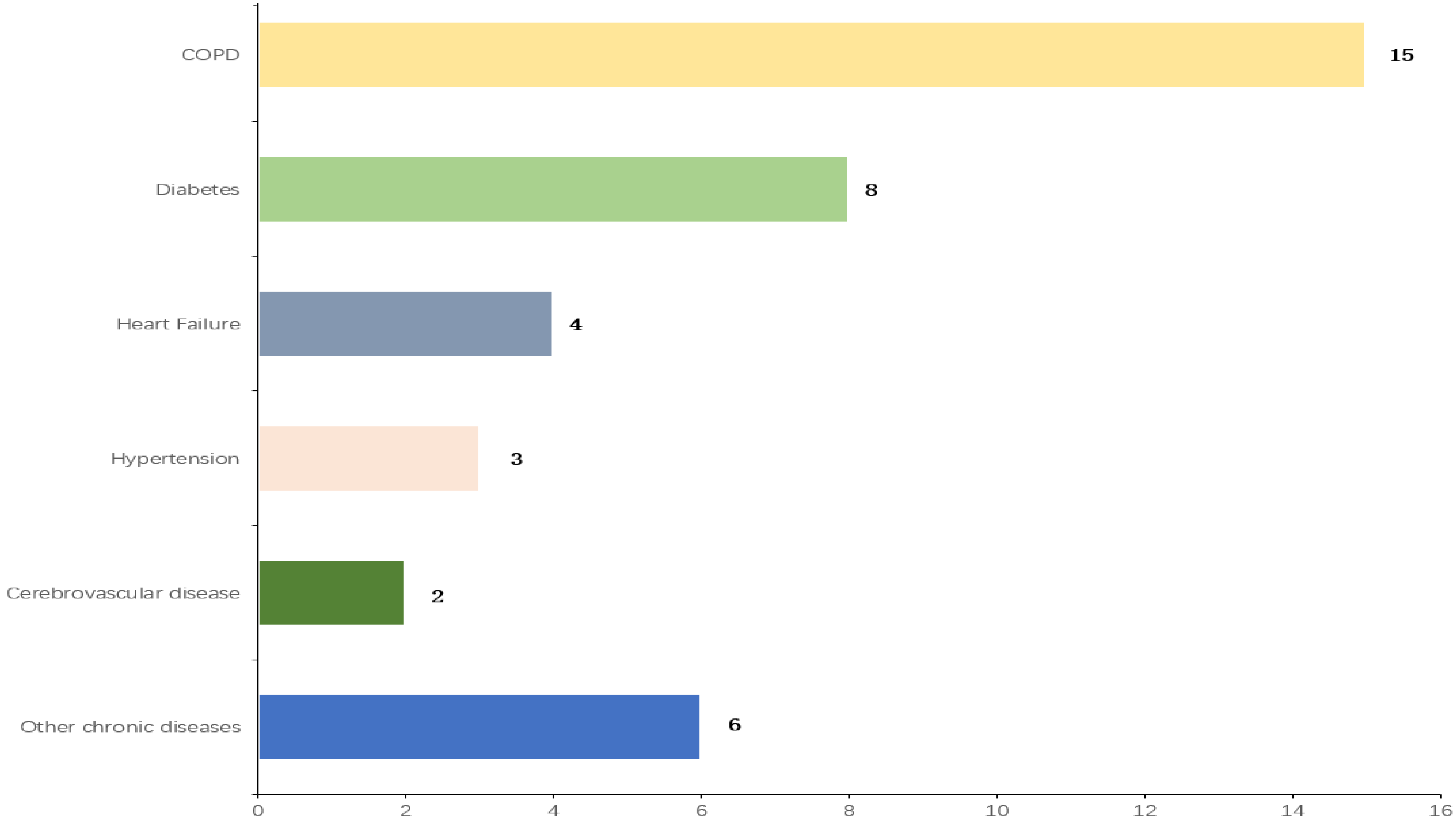

Figure 4.4 Chronic disease types involved in the included papers/studies

4.4.2 Digital health applications in elderly chronic diseases

Figure 4.5 presents the functions of digital health technologies that were focused on in the 31 included studies, which can be broadly classified into four categories: medical service functions (N=31), health management functions (N=27), disease management functions (N=24), and social management functions (N=4).

In the medical service function category, digital health technologies are effective tools to help elderly patients with chronic diseases obtain medical services more conveniently, meet medical needs, and help medical service providers optimize medical service processes and improve efficiency. These tools include digital platforms that facilitate interaction and communication between doctors and patients (N=13), online health education or skill training provided by healthcare professionals (N=10), remote video consultations with patients (N=3), online appointment scheduling for outpatient visits (N=4), access to medical reports (N=3), obtaining medication prescriptions and purchasing them for delivery to the home (N=4), and access to relevant medical files (N=2).

In the health management function category, digital health technologies are mainly used to improve the quality of life and physical health of elderly patients with chronic diseases rather than being limited to disease management. These tools include devices for monitoring routine physiological indicators such as blood pressure, blood sugar, and heart rate (N=6), online platforms for searching for health information (N=5), reminders and supervision of medication used to improve adherence (N=5), sensors for monitoring the health of elderly people with poor physical activity ability (N=4), smart wearable devices for real-time measurement of vital signs such as body temperature, blood pressure, blood oxygen, heart rate, sleep, and monitoring of the physical activity of the elderly (N=2), home alarm devices that user behavior sensing systems and Internet of Things technology to protect the lives of elderly people (N=2), virtual health coaches to assist elderly people with physical exercise and daily behavior management (N=2), and home intelligent robots to provide more convenient care services for elderly people (N=1).

In the disease management function category, digital health technologies are mainly used for the effective and timely management of specific chronic diseases in elderly people. This includes daily monitoring and collection of patient disease data, automatic formation of analysis reports, and providing a basis for doctors and patients to evaluate disease improvement (N=14), providing patients with chronic disease-related information and knowledge to achieve correct understanding and scientific management (N=4), using internationally accredited chronic disease assessment scales to provide patients with self-diagnosis and evaluation functions to ensure early detection of worsening symptoms of related chronic diseases (N=3), and building a regional collaborative medical service platform through home remote chronic disease monitoring and management systems to monitor the management of chronic diseases in elderly people in real-time (N=2).

In the category of social management functions, digital health technology is mainly used to provide social contact channels for patients, aiming to encourage social participation and strengthen social connections between elderly chronic disease patients and important family members or patients with the same chronic disease by providing family mutual aid platforms (N=3) and patient mutual aid platforms (N=1), and fully utilizing all social resources to reduce the social isolation and loneliness of the elderly and improve their quality of life.

Figure 4.5 Forms of digital health applications

In terms of the application of digital health technology in the scenario of elderly chronic disease, a total of 24 papers/studies focused on home health management, mainly reflected in the following four aspects: (1) using mobile health technology to monitor and collect disease data, consult with specialist doctors online, and make online clinic appointments; (2) developing remote medical technology, using digital health platforms for remote medical video, health tracking diary, disease self-diagnosis and assessment; (3) using the Internet to access medical files online, and query chronic disease information; (4) using smart wearable devices to measure vital sign data in real-time, elderly home fall alarms.

In addition, six studies focused on the application of digital health technology in community care for elderly chronic disease patients, a Swedish study focused on the beliefs, attitudes, experiences, and expectations of patients with hypertension, diabetes, and COPD regarding the application of digital health technology in primary healthcare (Nymberg et al., 2019); a Canadian study compared the intervention effects of using smartphones and not using smartphones for community health care for diabetes patients for six months (Pludwinski et al., 2016); another Canadian study explored the potential features of successful application and promotion of health management applications from the perspectives of doctors, nurses, pharmacists, and COPD patients (Alwashmi et al., 2020); a Norwegian study also explored the views of primary healthcare professionals on using digital health technology to prevent community care elderly people from being hospitalized (Gjestsen et al., 2020); a British study focused on the feasibility and potential effects of using social network map evaluation tools in COPD patient community care (Andreou et al., 2022); a Dutch study focused on the needs, barriers, and promoting factors for community elderly people to use online digital health applications to obtain general practice services (Vergouw et al., 2020).

Only one study focused on the application of digital health technology in hospital scenarios, focusing on the views of general practitioners, pharmacists, geriatric medicine experts, hospital social workers, and information personnel on the use of digital health technology for medication management through inter-professional cooperation, to improve the medication safety of elderly chronic disease patients of German-Turkish descent (Bird et al., 2022).

4.4.3 Comparison of characteristics of different digital health applications

Figure 4.6 presents the major categories and their temporal distribution of digital health application scenarios focused on the research literature.

We compared the situations of digital health applications in different time units, with each time unit being three years. From 2014 to 2016, the most frequently used function of digital health technology was health management (9 items, 60.00%), including the most involved functions being physiological data monitoring tools and internet health consulting services. The second most frequently used function was medical services (5 items, 33.33%). From 2017 to 2019, the most frequently used function of digital health technology was medical services (10 items, 50.00%), with the most involved function being online communication between doctors and patients through email or health applications. The second most frequently used function was disease management (6 items, 30.00%), with 5 of the functions involving patients collecting and monitoring disease data through health tracking diaries. During the COVID-19 pandemic from 2020 to 2022, the most frequently used function was medical services (23 items, 39.66%), with the most involved functions being online communication between doctors and patients and online health education. Disease management (17 items, 29.31%) involved the most functions, such as health tracking diaries and disease information inquiries. Health management (14 items, 24.14%) involved the most functions, such as patient medication management and internet health consulting services.

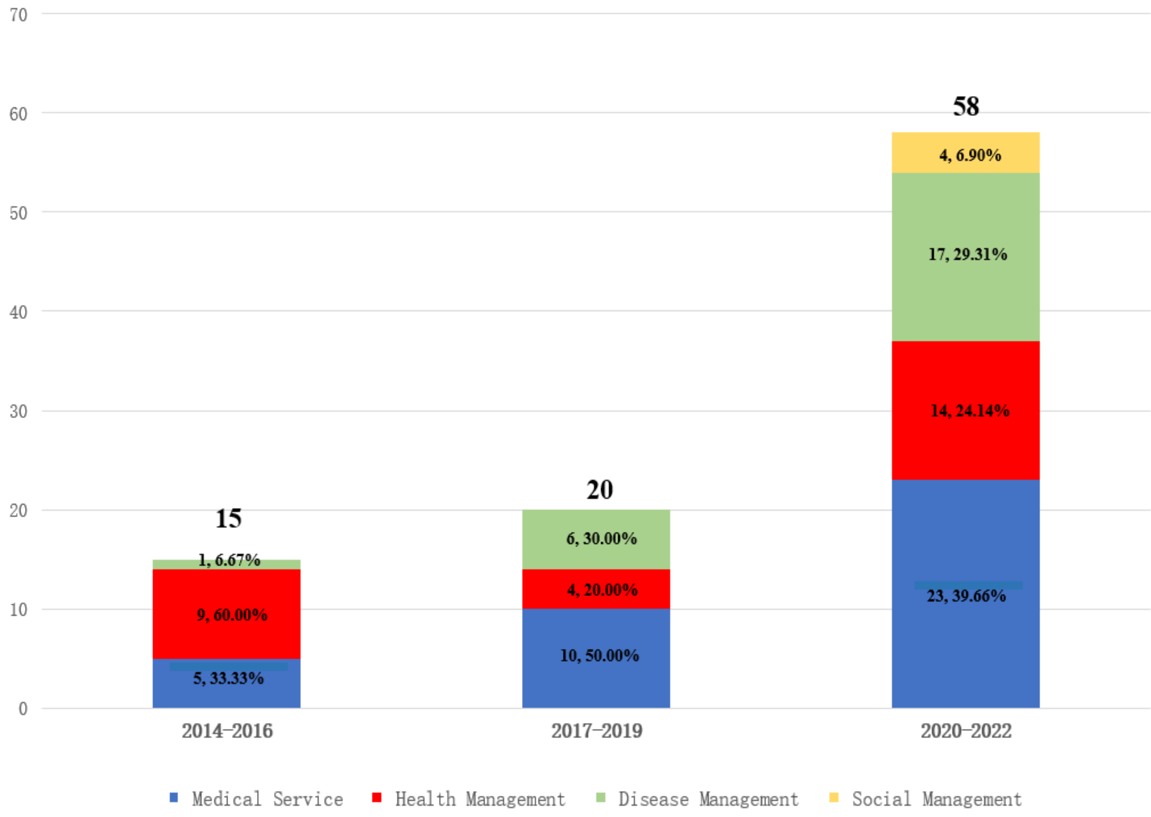

Figure 4.6 Application of digital health technologies in different periods

Figure 4.7 shows the distribution of digital health applications in the literature by international regions. Among the 18 European studies, the most used digital health technology application was medical services (23 studies, 38.98%), which mainly involved online communication between doctors and patients, online health education, and online medication purchase. The second most used application was health management (21 studies, 35.59%), which mainly involved physiological data monitoring tools, patient medication management, and Internet health consultation services. Among the eight studies from North America, the most used digital health technology application was medical services (8 studies, 44.44%), which mainly involved online health education. In disease management (5 studies, 27.28%), the most used application was health tracking diaries, while in health management (4 studies, 38.10%), the most used application was Internet health consultation services.

Among the five studies from Asia, the most used digital health technology application was disease management (7 studies, 43.75%), mainly involving disease information inquiries. The second most used application was medical services (7 studies, 43.75%), mainly involving online communication between doctors and patients. No digital health technology application for the social management of elderly patients with chronic diseases has been found yet.

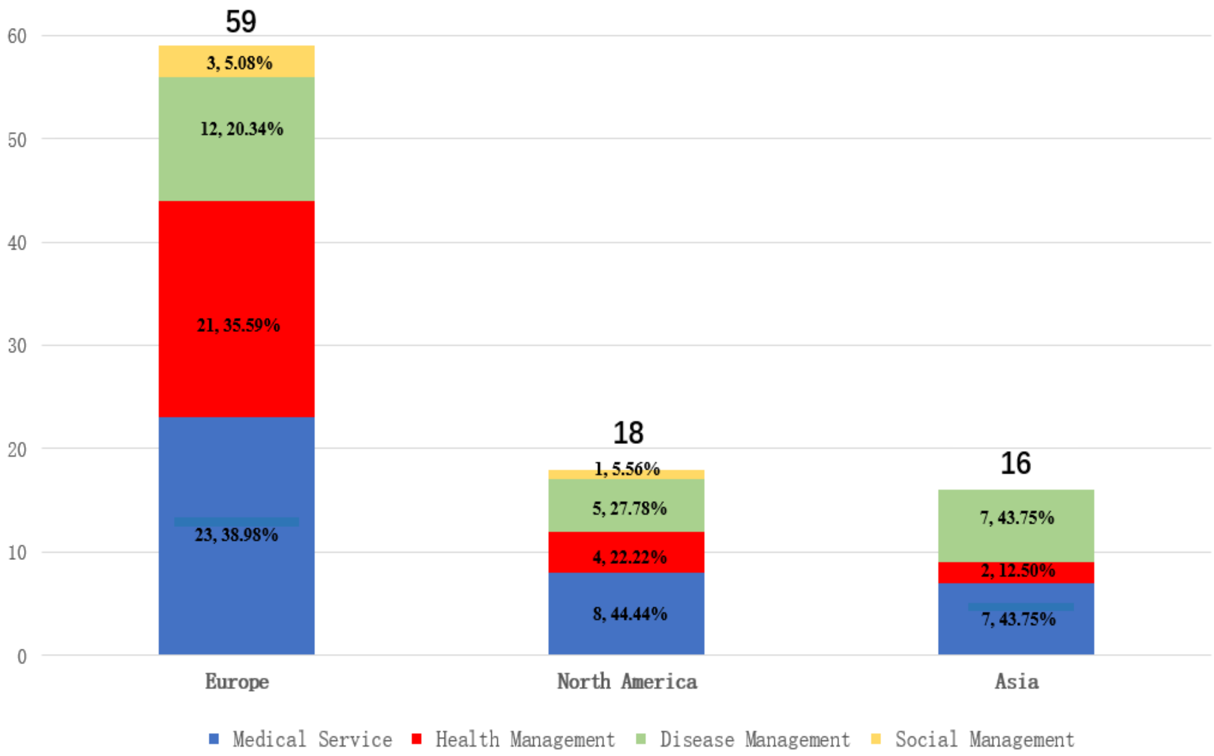

Figure 4.7 Application of digital health technologies in different regions

Figure 4.8 presents the research literature's digital health applications for different chronic diseases. The chronic diseases with the highest number of digital health applications are COPD, diabetes, heart failure, and hypertension. Among elderly people with COPD, the most used digital health technologies are medical services (16 items, 37.21%) and disease management (12 items, 27.91%). Among elderly people with diabetes, the most used digital health technologies are health management (9 items, 36.00%) and medical services (9 items, 36.00%).

No digital health technology application for the social management of elderly patients with chronic diseases has been found yet. Among elderly people with heart failure, the most used digital health technologies are disease management (7 items, 36.84%) and medical services (6 items, 31.58%). In elderly people with hypertension, digital health technology is mainly used for disease management (3 items, 50.00%).

For other related chronic disease populations (cerebrovascular disease, asthma, arthritis, Parkinson's syndrome, stroke, heart disease, chronic pain), the most used digital health technologies are medical services (13 items, 37.14%) and health management (11 items, 31.43%).

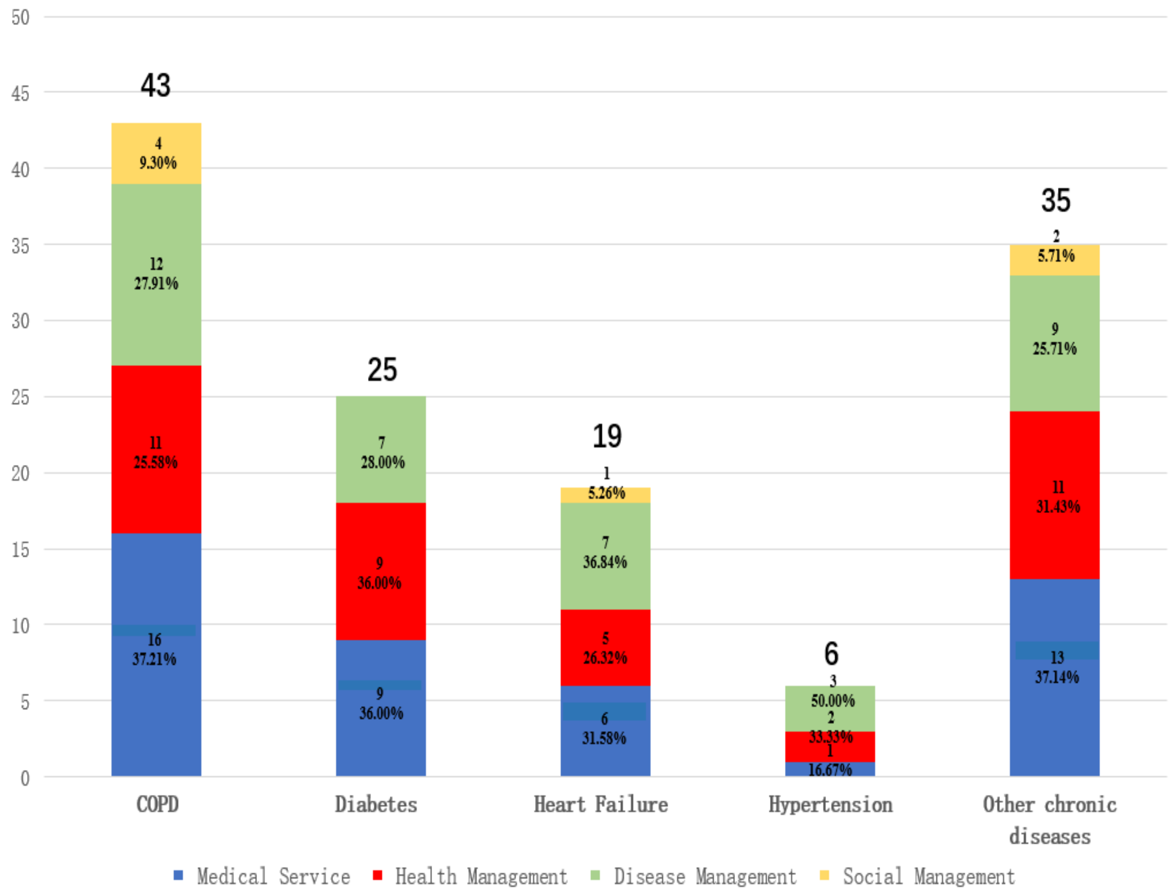

Figure 4.8 Application of digital health technologies in different chronic diseases

4.5 Procedure - qualitative analysis

Based on the included literature's inherent logic and conceptual meanings, we repeatedly scrutinized and condensed the information into complete and distinct statements, considered the smallest coding units. Initially, 268 initial concepts related to the research topic were extracted. Due to the large number of initial concepts and the presence of overlap, further refinement and merging of similar concepts were conducted cyclically.

Finally, 94 concepts and 35 initial categories (A01 to A35) were identified and summarized in Table 4.2.

Table 4.2 Open coding

	Concept	Frequency/time	Frequency/ %
A1 Ability to Accept	Lack of experience in use; lack of knowledge base; limited learning acceptance ability; spending a lot of time learning	24	8.96
A2 Interest	Dislike for technology; low initiative in learning;	13	4.85
A3 Awareness of Use	Lack of awareness of use;	10	3.73
A4 Technical Failure	Network fluctuations; hardware failures; registration and login difficulties;	14	5.22
A5Personalized Features	Inadequate navigation functions; lack of targeted health education; insufficient language affinity; difficult-to-read icons and fonts; complex and unnecessary service functions;	11	4.10
A6 Communication Form	Reduced opportunities for face-to-face communication; psychological distance; reduced social contact opportunities; reduced physical activity opportunities;	9	3.36
A7 Privacy Protection	Worries about privacy breaches; unwillingness to share health information; concerns about online fraud;	13	4.85
A8 Technological Anxiety	Worries about being unable to cope with urgent health conditions; worries about not being able to master technological knowledge; increased psychological burden of being monitored; psychological resistance to negative news; worries about being unable to adapt to updated and upgraded technology; feeling pressured to complete daily health tasks;	10	3.73
A9 Information Authenticity	Authenticity of physiological monitoring data; difficulty in distinguishing the authenticity of internet information; difficulty in proving the credibility of digital health technology;	10	3.73
A10 Economic Status	Poor personal economic status; unwillingness to pay for technology; technology prices are too expensive;	10	3.73

A11 Educational Attainment	Too low educational attainment;	5	1.87
A12 Age	Too old age;	4	1.49
A13 Health Status	Serious symptoms of illness;	2	0.75
A14 Effect	Improving quality of life; promoting health; providing medication advice; helping with dietary and nutritional management; increasing physical activity;	20	7.46
A15 Successful Use	Easy to operate; successfully mastering technological knowledge;	13	4.85
A16 Doctor-Patient Communication	Feeling cared for; long-term effective communication; sharing health information; being listened to;	16	5.97
A17 Trust	Trust in the medical profession;	4	1.49
A18FamilyMutual Assistance	Help with learning technological knowledge; remind to use technological tools;	3	1.12
A19 Medication Management	Provide a list of medications; develop reasonable medication strategies; remind to take medication;	8	2.99
A20 Health Education	Knowledge of chronic disease management; knowledge of healthy living;	6	2.24
A21 Doctor-Patient Cooperation	Video communication with medical staff; jointly formulate health plans;	5	1.87
A22 Physiological Data Monitoring	Real-time monitoring of physiological data; automatic transmission of health information to doctors; warning of abnormal situations;	3	1.12
A23 Health Diary	Daily recording of vital signs; automatic generation of analysis reports;	3	1.12
A24 Personalized Design	Disease information with targeted design;	6	2.24
A25 Operability	Easy to carry; clear and simple page design; tutorial guide for upgrading functions;	5	1.87
A26 Capability	Professional training in technology use; guidance manual;	3	1.12
A27 Literacy	Resistant to accepting new technology; fearful of new technology;	2	0.75
A28 Children's Support	Children help with learning technology;	3	1.12
A29 Mutual Help Among Patients	Patients share experiences with each other;	1	0.37
A30 Smartphones	Doctor-patient communication; online medication purchase; online outpatient appointment	8	2.99

A31 Digital Health Platform	scheduling; online report inquiries; disease information inquiries; Doctor-patient interactive platform; remote medical video; vital sign monitoring; patient medication management; health tracking diary; self-diagnosis and assessment of diseases; family mutual assistance platform; patient mutual help platform.	8	2.99
A32 Internet	Online access to medical documents; Internet health consultations; disease information queries;	6	2.24
A33 Smart wearable devices	Sensors; wearable devices;	3	1.12
A34 Community health care	Digital health care models;	6	2.24
A35 Hospital drug use	Interprofessional collaboration and medication management;	1	0.37

We further refined and classified the categories obtained through open coding and continuously analyzed the inherent logical relationships between categories, resulting in the summary and induction of 11 main categories (B1~B11), including awareness of abilities, technological factors, sense of security, individual factors, user experience, interpersonal support, service functions, subjective needs, family, community, and hospital, as shown in Table 4.3.

Table 4.3 Axial coding

Primary category	Initial category	Frequency/time	Frequency/%
B1 Awareness of ability	A1 receptivity; A2 interest; A3 awareness of use;	47	17.54
B2 technical factors	A4 technical faults; A5 individualized features; A6 form of communication;	34	12.69
B3 sense of security	A7 privacy protection; A8 technology anxiety; A9 authenticity of information;	33	12.31
B4 individual factors	A10 economic status; A11 education level; A12 age; A13 health status;	21	7.84
B5 experience of use	A14 effectiveness; A15 successful use;	33	12.31
B6 interpersonal support	A16 doctor-patient communication; A17 trust A18 family support;	23	8.58
B7 service functions	A19 medication management; A20 health education A21 physician-patient collaboration; A21 physician-patient collaboration; A22 physiological data monitoring; A23 health diary; A24 personalized design; A25 operability;	36	13.43
B8 subjective needs	A26 competence; A27 literacy; A28 child support; A29 patient support;	9	3.36

B9 family	A30 smartphone; A31 digital health platform; A32 Internet; A33 smart wearable devices;	25	9.33
B10 Community	A34 community health care;	6	2.24
B11 hospital	A35 hospital drug use;	1	0.37

By comparing and sorting the logical sequence and causal relationships among 94 concepts, 35 initial categories, and 11 main categories, this study systematically analyzed and summarized the core categories in all identified main categories, clarified the storyline of the data, described the attributes and dimensions of the main categories, and established the linkages between the core categories and other categories. Finally, based on the research theme, we summarized and categorized the four core categories of motivation, obstacles, needs, and scenarios, as shown in Table 4.4.

Guided by grounded theory, a storyline was developed: in different management scenarios of chronic diseases in the elderly, motivation and obstacles affect the use of digital health technologies by elderly chronic disease patients to varying degrees and continually generate new digital health needs, as shown in Figure 4.9.

Table 4.4 Selective coding

Primary category	Initial category	Frequency/time	Frequency/%
Facilitators	B5 experience of use; B6 interpersonal support;	56	20.90
Barriers	B1 awareness of competence; B2 technological factors; B3 sense of security; B4 individual factors;	135	50.37
Needs	B7 service functions; B8 subjective needs;	45	16.79
Scenarios	B9 family; B10 community; B12 hospital;	32	11.94

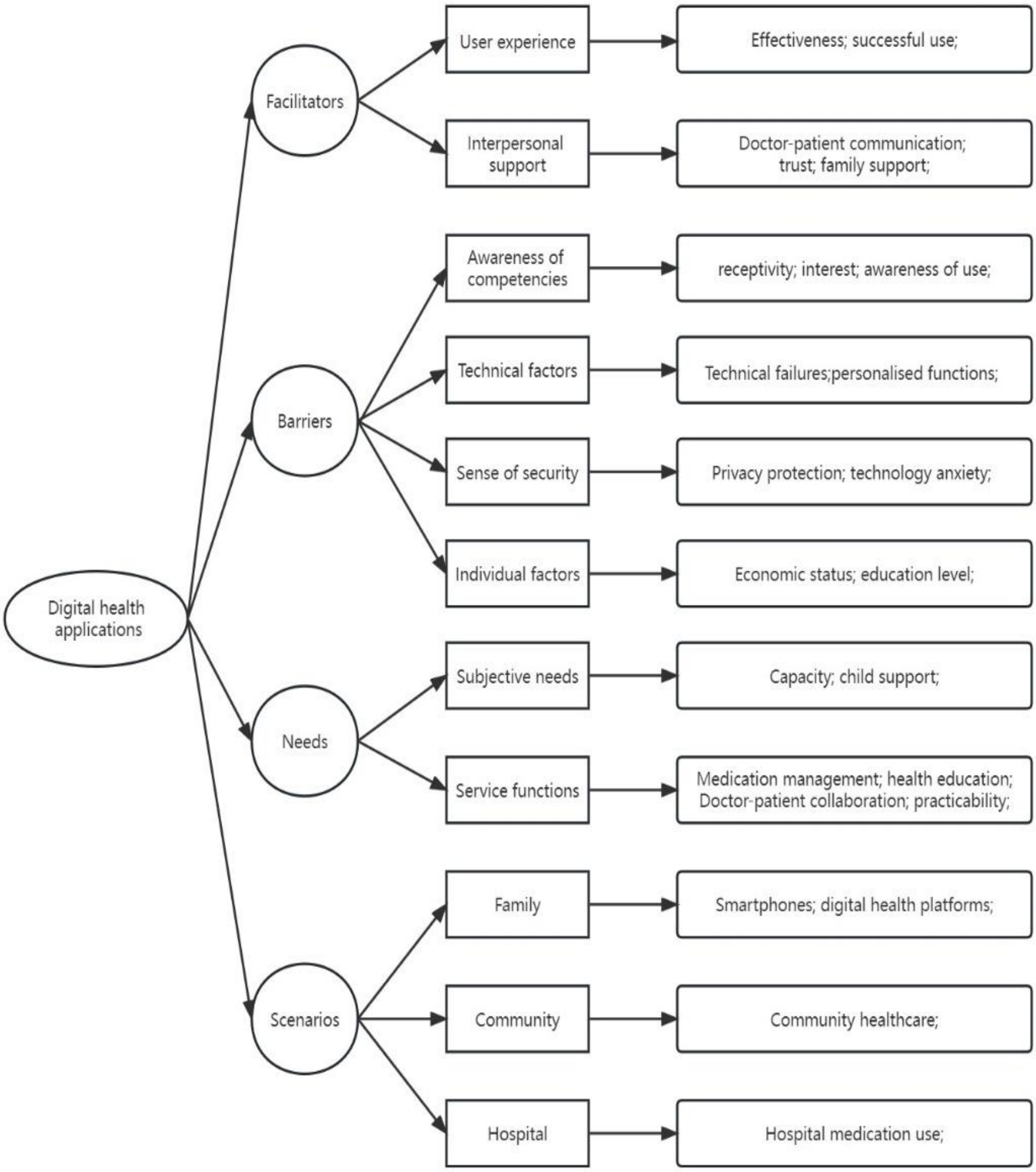

Figure 4.9 Theme words and related structures of digital health applications for elderly patients with chronic diseases

4.6 Discussion of the documental study

This documental study that complements the systematic literature review evidence that digital health technology has been widely applied and promoted in the elderly chronic disease population. Digital health primarily refers to the knowledge and practice of using digital technology to improve health, covering various digital health technologies such as mobile health, remote health, internet health, and smart wearables.

Digital health applications in elderly chronic diseases can be summarized into four dimensions: medical services, health management, disease management, and social management.

These functional services exhibit different degrees of application breadth and depth across different chronic disease areas, times, and regions. While using digital health technology, elderly chronic disease patients who succeed in using it significantly improve their health and quality of life, establish a sufficient trust relationship with medical professionals, and engage in good communication. The support and assistance of children also serve as a motivator for elderly chronic disease patients to use digital health technology. However, elderly chronic disease patients have insufficient acceptance, lack interest and awareness in digital health technology, and face obstacles such as technical failures, lack of personalized functions and non-face-to-face communication forms, security factors such as privacy protection, technological anxiety, and information authenticity, as well as individual factors such as advanced age, lower education level, poor health, and economic status.

The demand for digital health technology among elderly chronic disease patients includes seven levels of service functions: medication management, health education, doctor-patient communication, physiological data monitoring, health diary, personalized design, and operability. It also includes four subjective demand levels: ability, literacy, family, and peer assistance. Digital health technology is mainly applied in home health management scenarios using smartphones, digital health platforms, the internet, or smart wearables.

Based on preliminary findings from the literature, elderly chronic disease patients hold a positive attitude toward accepting digital health technology and are willing to use it daily. Some patients have already had experience using digital health applications.

4.6.1 Current situation of digital health applications in elderly chronic diseases

From a time span perspective, the overall trend in the past decade shows an increase in the number of studies on digital health technologies for promoting health and primary prevention in elderly patients with chronic diseases. After 2020, there was an explosive growth in research quantity, closely related to the outbreak of COVID-19. With the medical and health resources stretched thin around the world and the medical system facing enormous pressure, digital health technologies have broken the traditional healthcare service model, greatly improving the accessibility and convenience of medical services (Rani et al., 2021).

As time went on, the research focusses also continuously changed. In the early studies we reviewed, the most attention was paid to physiological data monitoring tools and Internet health consulting services (Piotrowicz, 2017). Subsequently, various communication tools became popular, and doctors attempted to monitor the home health management of elderly patients with chronic diseases through telephone, remote video, or home monitoring systems. After the outbreak of the COVID-19 pandemic, with the growing demand for health, the development and application of digital health technologies have been very rapid. Elderly patients with chronic diseases started to engage in medical activities such as online medication purchases and clinic appointments, report inquiries at home, and use health management platforms for disease tracking records and disease information inquiry to promote disease management and life improvement better (Bitar & Alismail, 2021).

In addition, social management functions have gradually received attention. As a low-cost and high-return social resource, family and patient mutual aid platforms can greatly help the elderly effectively manage chronic diseases (James et al., 2020). Although only four studies related to the social management of elderly patients with chronic diseases were included in our literature review, this situation may change with the introduction of new information tools such as applications (Boulos et al., 2011). This change is closely related to the rapid development of digital health technologies on the one hand and the growing health needs and improved living conditions of elderly patients with chronic diseases on the other hand (Kampmeijer et al., 2016).

From a geographic perspective, due to various social factors such as economy, politics, and population, the application of digital health technology in elderly chronic disease patients has been most extensively studied in developed countries in Europe and in the United States of America. The review results show that digital health technology is mainly used to promote medical services and health management for elderly chronic disease patients, especially through mobile devices, to expand communication channels between patients and healthcare providers, and to promote information exchange and feedback between doctors and patients. This may increase the possibility of providing health interventions to elderly chronic disease patients with difficulty accessing health resources (Hamine et al., 2015).

It was discovered that using mobile devices for health interventions has the advantages of being simple, convenient, cost-effective, scalable, personalized, and capable of providing real-time feedback on sensitive information (Whittaker et al., 2016). Hamine et al. (2015) have found similar results in a study focused on the impact of mHealth chronic disease management on treatment compliance and health outcomes. However, research and application of digital health technology in developing countries are relatively limited.

Both the number of studies and the scope of application of digital health technology lag far behind developed countries, limited to the treatment and management of a single disease. The communication between doctors and patients is still mainly conducted through SMS for health management. The low cost and low network requirements also promote the spread of applications, especially in low-income countries (Marcolino et al., 2018). These results may be related to the themes or concepts of the literature we reviewed.

From the perspective of chronic disease types, the most common chronic disease population that uses digital health technology is COPD patients. On the one hand, COPD has become a global public health problem, especially with high incidence and mortality rates among the elderly (López-Campos et al., 2016). On the other hand, COVID-19, as a global infectious disease with respiratory system characteristics, has increased the incidence of COPD, leading to a sharp increase in medical demand for COPD patients (Higham et al., 2020).

Self-health management is crucial for improving the health outcomes and quality of life of COPD patients, and digital health technology can improve patients' self-health management (Elbert et al., 2014).

According to our results, the most used digital health technologies are health-tracking diaries and doctor-patient online communication platforms. By monitoring and collecting disease data of COPD patients daily, automated analysis reports can be generated and transmitted remotely to doctors to detect respiratory system changes promptly and provide treatment recommendations to prevent further deterioration of the condition.

Similar results have been found in most systematic reviews, where remote health technologies are used for COPD management, and mobile devices and virtual technologies are widely used for health interventions outside medical institutions (Hallensleben et al., 2019). Lundell et al. (2015) found that remote medical care can improve COPD patients' physical activity but has no significant effect on patients with respiratory distress. However, Hanlon et al. (2017) discovered that remote medical care did not significantly reduce COPD patients' mortality rate or improve health outcomes. Sul et al. (2020) have found similar results.

Further research is needed to determine whether digital health technology can improve the quality of health management of COPD patients.

Secondly, the most common chronic disease population that uses digital health technology is diabetes patients. Previous studies show that online health education and health tracking diaries are the most used digital health technologies. Blood sugar changes in diabetic patients are closely related to daily behaviors such as dietary nutrition, physical activity, and sleep quality. Through implementing digital health interventions for diabetic patients, including increasing blood sugar and diet monitoring, daily physical activity measurement, and promotion of education and other activities, the interaction and communication between patients and providers can be strengthened to promote self-care among diabetic patients (Goyal & Cafazzo, 2013).

Seo et al. (2021) found that mobile phones and the internet are the most commonly used digital health technologies, with the most widely used functions being remote forms of monitoring and providing clinical advice or consultation to diabetic patients through text messages, web browsing, email, and video.

4.6.2 Factors that may affect the use of digital health technologies

A qualitative analysis of literature related to digital health found that elderly patients with chronic diseases have a positive attitude towards receiving digital health technology but are also influenced by some other factors. User experience and interpersonal support are the main driving factors. Elderly patients with chronic diseases can receive medication advice, help improve dietary and nutritional management, increase daily physical activity, and significantly reduce sedentary time using digital health technology, thus achieving the goal of improving quality of life and promoting health. This greatly enhances the initiative and enthusiasm of the elderly to use digital health technology (Bitar & Alismail, 2021; Goyal & Cafazzo, 2013).

On the other hand, elderly patients with chronic diseases can acquire digital health technology knowledge and skills well through self-learning or with the help of others, which gives them more confidence and interest to accept and explore the potential use of digital health technology in daily life and chronic disease management (Alwashmi et al., 2019; Portz et al., 2019). The impact of doctor-patient communication on interpersonal support is particularly prominent. Doctors or nurses who follow up on the health status of elderly patients with chronic diseases through long-term phone or video consultations make the elderly feel cared for and listened to (Portz et al., 2019).

Sharing the achievements or difficulties of using digital health technology with medical staff is considered a very important matter (Doyle et al., 2021), which can help reduce feelings of isolation and misunderstanding (Barenfeld et al., 2020; Pludwinski et al., 2016; Vergouw et al., 2020). At the same time, the trust relationship between elderly patients with chronic diseases and medical staff is also very important. Believing that medical staff are a prerequisite for discussing health status and experiencing digital health technology (Nymberg et al., 2019). In addition, the elderly patients' spouses or children who help them learn about digital health technology knowledge and remind them to use it in daily life can also change the attitudes and frequency of the elderly's use of digital health technology (Andreou et al., 2022; Jiang et al., 2022).

In elderly patients with chronic diseases, self-efficacy is a significant issue among influencing factors. Most studies have found that elderly patients with chronic diseases generally lack experience and knowledge of digital health technologies, and some elderly people believe that digital health technologies are too complex and require a lot of time and effort to learn, which indicates a lack of trust in their own learning ability and fear that they will not be able to master the use of digital health technologies proficiently (Andreou et al., 2022; Nymberg et al., 2019; Wildenbos et al., 2019).

Encountering setbacks or failures during the learning or use process will completely demotivate the elderly from learning digital health technologies (Portz et al., 2019). At the same time, several studies have found that some elderly people lack interest in digital health technologies and even have psychological aversion and resistance to new technologies, with technological anxiety and resistance to change increased by the digital divide, traditional culture, limited technological skills, and information-seeking behaviors (Hoque & Sorwar, 2017; Islam et al., 2011; Vergouw et al., 2020).

Among the technological factors influencing digital health applications, technical malfunctions receive considerable attention. When elderly patients with chronic diseases encounter network signals (Andreou et al., 2022) or hardware malfunctions (Nymberg et al., 2019), they feel frustrated, angry, and disappointed, which leads to a reluctance to use digital health technologies again. In addition, the overall design of digital health lacks friendliness to the elderly, such as complex login procedures (Vergouw et al., 2020), unclear navigation (Wildenbos et al., 2019), difficult-to-read fonts and patterns (Jiang et al., 2022), and complex use of digital health platforms (Portz et al., 2019).

On the other hand, digital health technologies change the social communication form of the elderly, and communication through mobile phones or networks reduces the opportunity for face-to-face contact (Alwashmi et al., 2020), making people's relationships more distant (Jiang et al., 2022; Lundell et al., 2020). Elderly patients with chronic diseases are more disposed to go to the hospital in person to buy medicine or make appointments, as this allows them to leave their homes and increase their physical activity opportunities.

A sense of security is also important for elderly chronic disease patients using digital health technologies. Some patients consider the disease condition to be very private information and are unwilling to share it with unrelated personnel (Andreou et al., 2022; Herrmann et al., 2020). They become more cautious when using the Internet, fearing online access to health information or medical services may result in network fraud or privacy breaches (Alwashmi et al., 2019).

Elderly chronic disease patients are full of anxiety and fear when using digital health technologies, worrying that these technologies may not be able to deal with health problems in emergencies (Nymberg et al., 2019) or that they may not be able to grasp information technology knowledge or adapt quickly to updated and upgraded functions (Portz et al., 2019). They often encounter negative online news related to their disease, leading them to develop a resistance to solving health problems through the Internet (Jiang et al., 2022).

In addition, the authenticity of information is also an important factor hindering elderly chronic disease patients from using digital health technologies. Some elderly people give up using these functions and services because they cannot distinguish the authenticity of internet data (Hurmuz et al., 2022; Jiang et al., 2022; Townsend et al., 2015).

From our literature review we deduce that there are more research focuses on elderly chronic disease patients using digital health technologies in the domain of home self-health management. The application scenarios of home digital health are more accepted and used by this population. The application scenarios of this population in communities and medical institutions still need to be further explored (Davoody et al., 2016).

Elderly chronic disease patients will constantly generate new health demands using digital health technologies. When these demands can be met on time, it will promote the active acceptance and use of digital health technologies by elderly chronic disease patients. Otherwise, it will have a hindering effect. The perceived situation of elderly chronic disease patients using digital health technologies is very important.

For example, health education and medication management based on digital health technologies can help improve the sense of recognition of elderly chronic disease patients for these technologies. This concept comes from the UTAUT theory, where the model is consistent between individual effort performance expectations (Hoque & Sorwar, 2017). In other studies based on the UTAUT theory model, De Veer et al. (2015) also found that effort expectations and performance expectations are highly correlated with the willingness of elderly chronic disease patients to use digital health technologies. Magsamen-Conrad et al. (2015) affirmed that expectations are more important than performance expectations in predicting the use of digital health technologies by elderly chronic disease patients.

In the exploration and development of future digital health, we should consider not only the driving and hindering factors mentioned earlier in this discussion – such as, user experience, interpersonal support, the support from others, self-efficacy, psychological aversion and resistance, technical malfunctions –, but also the feedback of elderly chronic patients – to be incorporated into the design, participation, and delivery processes. Then relevant data may be collected, by a strategy implemented through focus groups, individual interviews or questionnaires, and pilot studies – as you present and develop in the two subsequent studies.

Through this study we have gained a general understanding of the scenarios, needs, and challenges of digital health technology applications for elderly patients with chronic diseases (see Figure 4.9). However, of the 31 papers included in the study, only one was reported from China. With the rapid development of digital health technologies and applications in China, there is a need for in-depth research on elderly chronic disease patients and digital health in the real world. Considering this, we designed and conducted two real-world studies in our follow-up research work.

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Chapter 5: Study 2 – Qualitative Research

5.1 Presentation of study 2 – focus group discussions

In this study, we designed the interview outline by referring to themes and concepts obtained from the literature review and documental study. In this part of qualitative research, we verify the perceptions of elderly chronic disease patients – through two focus group discussions, using grounded theory for the data text analysis – to explore the possible types of digital health application scenarios and how they use, and adopt, digital health technologies. So, we may understand the main applications, needs and problems of digital health technology in elderly patients with chronic disease in China, particularly in Shanghai.

5.2 Objectives

(1) Verify the types of digital health application scenarios and the utilization of digital health technology by elderly chronic disease patients in Shanghai.

(Research Objective 2)

(2) Verify the needs of elderly chronic disease patients for digital health technology and application scenarios.

(Research Objective 3)

5.3 Methodology

5.3.1 Participants description

In this study there were 15 participants, comprising nine men (60%) and six women (40%), with an average age of approximately 66 years. The educational background of the participants was primarily at the level of junior high school and high school (7 out of 15, 46.7% junior high school; 7 out of 15, 46.7% high school). The chronic conditions reported by the participants included hypertension, coronary heart disease, diabetes, stroke, and chronic obstructive pulmonary disease. Most of the participants had experience using digital health applications independently or with assistance from others (13 out of 15, 86.7%).

5.3.2 Inclusion criteria and exclusion criteria

Inclusion Criteria:

(1) Individuals with 60 years or above;

(2) According to the International Classification of Diseases, 10th Revision (ICD-10) diagnostic criteria for chronic diseases, we collected data from elderly patients with five specific chronic diseases: essential (primary) hypertension (I10.x00), type 2 diabetes (E11.900), coronary atherosclerotic heart disease (I25.103), stroke (I64.x00), and chronic obstructive pulmonary disease (J44.900);

(3) Patients capable of independent judgment and understanding, able to fill out the questionnaire and to participate in the discussion;

(4) Residing in Shanghai for at least six months;

(5) Voluntary participation and consentient to use their data in this investigation.

Exclusion Criteria:

(1) Critically ill emergency patients;

(2) Patients involved in medical disputes.

5.3.3 Procedure

Before starting the focus group discussion, the research team explained the ethical situation to the participants – considering that this study has been approved by the Ethics Committee of Xinhua Hospital affiliated with Shanghai Jiao Tong University School of Medicine – and introduced the project background. After the patients' informed consent, a brief questionnaire was used to collect the basic information of the participants.

Subsequently, the research group played a video introducing the application of digital health technology in different medical institutions to help patients better receive medical services (this video is from Shanghai Children's Medical Center), introducing the concept and application effects of digital health technology to patients. Each discussion between the participants and the researcher begins after the researcher present the main goal and purpose of the focus group, and the participants are introduced to each other. Each focus group discussion may take between 60 and 90 minutes to ensure that all participants have sufficient opportunities to speak, discuss with others, and communicate. In this study, two groups of focus group discussions were conducted at Xinhua Hospital Xinhua Hospital affiliated with Shanghai Jiao Tong University School of Medicine, with one group of seven participants and another group of eight participants.

During the session, the researcher asks questions based on the discussion outline and the communication, and feedback, from participating patients. Two assistants are responsible for recording the situation of each participant during the discussion and, with his/her consent, recording the entire discussion to facilitate subsequent text organization and ensure the accuracy and completeness of the records. Focus Group Interview Field Notes Sheet is presented in Annex F.

5.3.4 Data processing techniques

The adopted data processing method is based on Colaizzi's seven-step analysis approach for qualitative analysis. Colaizzi analysis is the more common method of analysing interview data, while qualitative interview data is analysed, collated and collected, and refined in a cyclical process (Hair et al., 2022).

The analysis of qualitative data employs an inductive approach. The first step was to read through the text to ensure that no valuable details were missed, to identify expressions that were closely related to the research question and that were rich in meaning, and to analyse the implications of these. Next, recurring ideas were coded, converting specific elements of the text into category labels that could be easily quantified and analysed in a comparative manner. Subsequently, commonalities and interrelated themes were identified by comparing the various ideas. Finally, the theoretical framework was refined by organically integrating these refined themes. In this process, two professional researchers accurately describe the collected data, ensuring that all details are recorded.

Textual data from focus group discussions are imported into NVivo 12 software to form raw files. Concept and thematic identification from sentence analysis, descriptive statement writing to better understand these themes, and a recursive process of confirming and adjusting the analysis are performed. The data is repeatedly studied, themes are identified, and descriptive statements are written to ensure the accuracy and completeness of text analysis. Finally, potential thematic structures are identified through the study and analysis of the data, usually encompassing connections, interactions, and influences between themes.

Any contentious content during text analysis is discussed and determined with two additional researchers to ensure the accuracy and scientific rigor of the final thematic formation.

5.4 Results

First, we highlight as main categories: scenarios, facilitators, barriers, and needs. It is important to indicate that:

(1) Each quoted paragraph was written in italicized, and the group number and participant code represent the participant's identifier and the number of the investigated focus group.

(2) Due to the colloquial expressions used by participants during interviews, some abbreviations were supplemented, or terms mentioned by the participants were explained in parentheses and italics in the process of excerpting quotes. This was done to enhance the coherence of the statements and clarify the semantics.

For elderly patients with chronic diseases, four main digital health scenarios have been identified, encompassing online appointment scheduling, online information retrieval, virtual consultations, and remote monitoring. Among these, online appointment scheduling emerges as the most frequently used digital health application. Whether assisted by family members or operating independently, most participants have developed a habit of prioritizing online appointment scheduling before seeking outpatient medical care.

Subcategories for Scenarios:

Online Appointment

Some participants mentioned that they would research the background information of doctors visiting the hospital through the Internet before scheduling an appointment. They combine this information with their own medical conditions to seek treatment from doctors who specialize in their specific ailments.

"The hospital's app, the most convenient for appointments, (you can choose) any day, (you can choose) any specialist, registration... this is the most convenient, (these features) are the ones I use the most."(Group 1, Participant 2, Female, 62 years old)

"The only function we use is appointment registration, (this function) is used quite frequently." (Group 2, Participant 4, Male, 72 years old)

"(On the internet) check which hospital, find which doctor, all very convenient, you can also see which diseases these doctors are mainly good at."(Group 1, Participant 2, Female, 62 years old)

Online Inquiry

Another familiar digital health application for many patients is accessing electronic medical examination reports. After completing various medical tests at the hospital, patients can directly retrieve their medical examination reports through dedicated mobile applications.

"The hospital app, when I click on it, I can see the results of the ultrasound and other medical treatments that I've had, all of them."(Group 2, Participant 3, Male, 72 years old)

"In the past, there were so many indicators on the laboratory tests that we didn't know what

they meant. Now when we search online, we can know which disease the indicator is used to check."(Group 1, Participant 2, Female, 62 years old)

Online Consultation

When a few patients with limited mobility need medical attention, their children assist them in using online health service platforms. Under the guidance of doctors, they experience the convenience of remote consultations and medication management. Some participants shared instances of benefiting from digital health without initially realizing it. Remote monitoring technology promptly detected anomalies in physiological indicators, allowing healthcare professionals to identify and address issues on time, thus avoiding unforeseen consequences due to changes in their health condition. When a few patients with limited mobility need medical attention, their children assist them in using online health service platforms. Under the guidance of doctors, they experience the convenience of remote consultations and medication management.

"On the internet, (knowing) what illness you have, how to see (a doctor), what medicines (you need to take), this is quite good (function)."(Group 1, Participant 4, Female, 67 years old)

"On the internet, you can make appointments, ... you can communicate with the doctor, ask a few questions. It's quite convenient. Sometimes, when you feel uncomfortable, what medicine to take (on the internet) you can communicate with the doctor."(Group 1, Participant 2, Female, 62 years old)

Remote Monitoring

Some participants shared instances of benefiting from digital health without initially realizing it. Remote monitoring technology promptly detected anomalies in physiological indicators, allowing healthcare professionals to identify and address issues on time, thus avoiding unforeseen consequences due to changes in their health condition.

"My blood sugar suddenly dropped, and the nurse called me immediately... this remote monitoring is very good."(Group 2, Participant 3, Male, 72 years old)

"(The remote monitoring device) I installed on my belly, used to measure blood sugar, automatically measured, I heard it needs to measure blood sugar more than three hundred times a day."(Group 2, Participant 7, Male, 60 years old)

"I have a 'Sense' (this is a wearable blood sugar monitoring device) installed on my arm, it can measure blood sugar."(Group 2, Participant 2, Male, 62 years old)

This study further categorizes the primary facilitators and barriers that elderly patients with chronic diseases encounter regarding digital health applications.

Subcategories for Facilitators:

Reduced Time for Medical Visits

Participants indicated that compared to traditional medical models, digital health applications offer a faster and more efficient medical experience. With the assistance of online appointment scheduling, patients can schedule and register for appointments online before visiting the hospital, as well as pre-book various examinations through mobile applications. Due to this, participants can flexibly arrange medical appointments, precisely manage the time required for medical visits, and reduce waiting times, earning praise from the participants.

"The key is the time saved... Now after we make an online appointment, it generally takes less than an hour. After arriving at the hospital, we can see the doctor."(Group 2, Participant 1, Male, 69 years old)

"In the past, when seeking medical care, we had to come very early and wait for a long time. There were also queues at the payment window, waiting for several hours. Now, it is indeed convenient. (Online) appointments are made within a time frame. I come a little earlier, and it doesn't take long to see the doctor."(Group 2, Participant 4, Male, 72 years old)

Prompt Awareness of Health Conditions

Medical examination reports can be accessed through specialized mobile apps, eliminating the need for patients to travel back and forth to the hospital to obtain reports, which is particularly convenient for elderly individuals with limited mobility. Some participants noted that various medical examination reports can now be stored on mobile devices, allowing them to be viewed at any time, greatly aiding in disease management.

"When I go to the outpatient clinic after I finish seeing the doctor, I go home, and the results of the medical condition are already visible on my phone... It's really fast, and it's a kind of help for us elderly patients."(Group 1, Participant 2, Female, 62 years old)

"I know all my information now. I downloaded an app, and all kinds of CT images and examination results can be viewed."(Group 1, Participant 1, Male, 64 years old)

Streamlined Medical Visit Process

Participants expressed high satisfaction with online appointment scheduling, payment, and even medication delivery applications, praising their reduction of multiple queueing processes during medical visits. Digital health technology simplifies the medical visit process, and participants shared personal experiences of how such optimizations genuinely assisted frail elderly patients.

"This time when I registered, I registered directly, paid all the money together, and I didn't have to queue up. I'm really happy, it's very fast."(Group 1, Participant 3, Female, 66 years old)

"I think digitalisation is quite advanced these days, and if I make an appointment in the

evening, such as an outpatient appointment, I can reserve whatever time I want to come and see the doctor. It's reassuring when you've booked an appointment."(Group 1, Participant 7, Female, 61 years old)

Subcategories for Barriers:

Lack of Trust in Digital Health Technology

Some participants expressed concerns about the reliability of certain digital health applications, especially when the technology extends beyond general outpatient services (such as appointments and payments). When digital health technology assumes the role of a doctor, particularly in disease diagnosis and treatment, some participants exhibited distrust, especially towards the diagnostic advice provided by online consultation platforms. They stated uncertainty regarding the authenticity and accuracy of online health advice, questioning whether it originates from professional medical opinions.

"I worry whether the answers from the robot doctor are accurate."(Group 2, Participant 2, Male, 62 years old)

"How can I trust this robot? Of course, I have concerns."(Group 2, Participant 7, Male, 60 years old)

Decline in Physiological Function

Participants pointed out that age-related declines in vision and hand dexterity make operating digital health application devices or online systems, including smartphones, very challenging. Additionally, some participants noted that despite attempting to learn how to operate digital health applications, rapid forgetfulness requires elderly individuals to invest more effort in learning. A few participants with cerebrovascular diseases, causing cognitive decline, faced even greater difficulties in learning digital health technology.

"I can't see it with my eyes... As I've gotten older, my eyes can't see anything (referring mainly to not being able to see various prompts on digital health applications clearly)."(Group 1, Participant 4, Female, 67 years old)

"Because we are all quite old, it's a bit difficult to study and understand on our own."(Group 2, Participant 4, Male, 72 years old)

Lack of Willingness to Learn and Use Due to Low Frequency of Digital Health Application Use

Some participants mentioned that their stable disease control and infrequent hospital visits make using digital health application functions such as online appointment scheduling and viewing examination results on a mobile device less necessary. These participants feel there is currently no need to learn this new technology. Many participants prefer visiting community health service centers when obtaining medication for chronic diseases. These institutions, like major comprehensive hospitals, have manually staffed service windows in key service areas and, due to the relatively low number of patients in community clinics, can ensure the quality of traditional manual service modes.

I" don't need this thing; I only go to the hospital once a year... I don't want to learn this kind of thing."(Group 1, Participant 3, Female, 66 years old)

Fatigue from Learning New Information

Some patients explicitly stated that, upon entering old age, they lack enthusiasm for learning how to use new digital health technologies. Some participants delegate the use of this technology to their children when needed. Older individuals who can easily obtain help from others are less willing to learn digital health technology.

"We are old, relying on our children... We are lazy and don't want to learn."(Group 1, Participant 5, Male, 75 years old)

Design Issues in Digital Health Products

Many participants pointed out design issues in certain digital health technology products, such as small font sizes, unclear identification, and a propensity for causing mistakes. Additionally, several patients raised concerns about the overly complex functionalities of some smart wearable devices, where multiple data sets are displayed in a small screen space, which needs to be clearer. These issues increase the difficulty for the elderly in learning and using digital health technology.

I" think it has too many functions, too many numbers; sometimes I find it troublesome." (Group 1, Participant 2, Female, 62 years old)

Along the interviews, the researchers identified participants' needs regarding digital health applications.

Increase Promotion

The data from the focus groups reveal that many participants need to gain a greater understanding of digital health applications, with information primarily sourced from introductions by their children and recommendations from fellow patients. Elderly patients remain relatively unfamiliar with the extensive functionalities and scenarios of digital health applications, and television media serves as a more familiar and accepted promotional medium among the elderly population.

"Regarding digital health technology, the most crucial aspect is promotion. The more it is promoted, the more it leaves an impression."(Group 2, Participant 1, Male, 69 years old)

Design Simplification

When expressing their expectations for digital health applications, many consistently emphasized the desire for simplified application interfaces. Participants highlighted that the elderly population is prone to being misled by complex functionalities and unnecessary information, especially when the interactive interface design of digital health applications is intricate. This includes both mobile digital health applications and other wearable devices. Some participants pointed out that a clear and concise interface would reduce the likelihood of making mistakes.

"For the interface of digital health products, it should be simplified so that older individuals can easily understand. It shouldn't be too complex; when you click into the interface, it should be for appointments, very clear, not too much, as too much can be confusing for us."(Group 1, Participant 2, Female, 62 years old)

"I hope the operation of digital health applications is simpler. The simpler, the better."(Group 2, Participant 5, Male, 60 years old)

Assistance from Others

In using digital health applications, participants demonstrated a reliance on younger family members, particularly co-residing children. Many participants mentioned that their first instinct when using digital health applications is to seek help from their children. However, at times, assistance from children may need to be prompter and more proactive.

"I don't handle digital health products myself; I wait until my children are around, then I ask the younger generation to handle it."(Group 1, Participant 4, Female, 67 years old)

"We rely more on our children now, and the younger generation cares for us. We don't need to handle digital health products ourselves; they take care of everything."(Group 1, Participant 5, Male, 75 years old)

Reliable Training

During the focus group sessions, some participants also showed a keen interest and willingness to learn about digital health applications. They reflected that there is currently a lack of platforms that cater to the learning and operation needs of the elderly population regarding digital health applications. They expressed a desire for more convenient training opportunities within the community and suggested that training could be organized by the government, hospitals, and trusted medical professionals.

"I hope there is a platform that can help older adults understand, become familiar with, and operate various aspects, referring to training related to digital health and applications. It would be best if there were such a platform in the community, allowing elderly friends to learn. Let everyone receive assistance and services on this platform."(Group 2, Participant 2, Male, 62

years old)

"The key is to gradually popularize and provide organized guidance to the elderly."(Group 2, Participant 1, Male, 69 years old)

More Features

After gaining insights into the current applications of existing digital health technologies, some participants expressed a demand for the future development of additional features in digital health applications. They hope that these applications will play a more significant role in the daily lives and healthcare of elderly patients.

"If medical consultations could be conducted at home, it would be extremely convenient." (Group 2, Participant 2, Male, 62 years old)

5.5 Brief conclusions of study 2

The researchers conducted focus group discussions to understand the scenarios of digital health applications for elderly chronic disease patients, as well as the facilitators, barriers and needs in the process of use.

The digital health application scenarios encountered and used by elderly patients with chronic diseases mainly involved online appointments, online enquiry, online consultation, and remote monitoring. Compared with traditional medical treatment, digital health applications have the advantages of reducing the time of medical treatment, quickly learning about the condition, and simplifying the process of medical treatment, which promotes the acceptance and use of digital health applications by elderly patients with chronic diseases.

However, due to the mistrust of digital health technology, physiological downgrading, infrequent use of digital health apps, and burnout in learning new knowledge, coupled with the need to improve the aging-appropriate design of digital health products, the subjective willingness of older patients with chronic diseases to adopt digital health apps and their actual behaviours have been impeded to a certain extent. During the focus group discussions, older patients with chronic diseases expressed some needs for digital health technology and applications, including the hope for more promotion and publicity, more reliable training, more functionality in a simplified design, and the need for help from others in the process of using it.

Through this study, we refined the main subcategories, including scenarios, facilitators, barriers and needs from the focus group interview texts in a qualitative way. Therefore, we have gained a preliminary understanding of the perceptions of real-world older people with chronic illnesses on the acceptance and use of digital health technologies and applications and have collected specific perspectives from older people with chronic illnesses around the four dimensions of facilitators, barriers, needs, and scenarios, as well as further clarifying the direction of this study.

In the second study（a qualitative study, using focus group), as in the first study (a documental study, to explore the more relevant literature on the main topic, through textual analysis, based on grounded theory), we categorised concepts and themes around the application scenarios, needs, facilitators and barriers to the use of digital health technologies for older patients with chronic illnesses, and the perspectives of older people in the real world. We found that in the application scenarios section, both Chinese and foreign patients were relatively consistent, focusing mainly on healthcare services. However, we also found some differences in the scenarios. As an example of patient needs, in the first study, it was found that the needs of the elderly were mainly to optimise the functioning of health services, improve personal literacy and peer support. However, in our focus group discussions, patients' main concerns were increased promotion of digital health technologies, trusted training, simplified product design, increased product functionality, and the need for help from others. Taking facilitators again as an example, the literature concludes that experience of use and interpersonal support are important, whereas the older patients with chronic diseases in focus group discussions mainly valued a good experience of access to healthcare due to digital health technologies. These differences make us realise that there may be differences in the prerequisites and internal and external environments for the adoption of digital health technologies in older chronic populations in different geographic areas, and so there is a strong need for theoretical model-based research on influencing factors to further clarify the situation in these specific populations.

In addition to this, we verify that the focus groups are qualitative with small single-centre sample size, some subjective data, and a lack of more objective quantitative evaluation. Therefore, as a follow-up, a multi-centre, large-sample, real-world study will be conducted, which will be based on theoretical modelling – proposing a new conceptual model and developing a questionnaire to obtain data that allow us to test and validate the theoretical-conceptual model – to explore the issues raised in this research more objectively, in a quantitative analysis.

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Chapter 6: Study 3 – Quantitative

6.1 Presentation of study 3 – inferential

This study is a quantitative study conducted in 12 medical institutions through a questionnaire. The participants are elderly chronic disease patients residing in Shanghai, mainly focusing on evaluating digital health applications. We propose and analyse an integrated theoretical-conceptual new model – designated as KAP-UTAUT – using SPSS and SmartPLS software – to explain the adoption of digital health technologies by elderly chronic disease patients.

The research validated the hypotheses proposed by the integrated model and explored the interrelationships and mechanisms of action among the variables.

6.2 Objectives

(1) Propose – and validate – a theoretical-conceptual model to explain the acceptance and use of digital health technologies by elderly chronic disease patients.

(Research Objective 4)

(2) Identify the factors that affect the acceptance and use of digital health technologies by elderly chronic disease patients.

(Research Objective 5)

(3) Propose suggestions to facilitate the adoption of digital health technologies by elderly chronic disease patients.

(Research Objective 6)

6.3 Conceptual model proposed and hypothesis

6.3.1 Conceptual model proposed

In Section 2.4, we reviewed some models and briefly introduced the basic variables in UTAUT. Meanwhile, we also mentioned the KAP model in section 2.5.1. As mentioned earlier, the KAP model is a classic theory in health communication, mainly used to study which important factors play a role in changes in people's health behavior. This theory particularly emphasizes the role of knowledge and attitudes. The formation of healthy behavior is not achieved overnight but is a gradual process. The starting point of this process is the understanding of health-related knowledge. The accumulation of this knowledge has a significant impact on the formation of individual health-related attitudes, some of which may be positive, while others may be negative. Following closely behind is the individual's attitude, which plays a crucial role in ultimately promoting the implementation of individual health behaviors.

According to previous research findings, the establishment of a positive attitude towards health can help promote the emergence of healthy behaviors. The Knowledge-Attitude-Practice theory has brought a lot of inspiration to the field of digital health, especially in the application of the technology acceptance and use theory. By applying the Knowledge-Attitude-Practice theory in the field of digital health, the influencing factors that drive the formation of digital health behavior can be divided into internal and external factors. We summarize external factors into those that contribute to the acquisition or formation of digital health knowledge, as well as external environmental conditions that contribute to the formation of digital health attitudes and digital health literacy. We view internal factors as an important catalytic process that occurs entirely within an individual's mindset. There are many factors that make up this catalytic process, including positive and negative factors. Under the combined influence of these factors, individuals form attitudes towards digital health and thus nurture their digital health literacy. Based on individual digital health literacy, it generates digital health behaviors that we may observe in our daily lives.

After analyzing the basic framework of the Unified Theory of Acceptance and Use of Technology (UTAUT), we found that in this study, Social Impact (SI) mainly includes important populations that may have an impact on elderly chronic patients, such as family members, relatives, teachers, or healthcare workers, who are very likely to pass on their acquired knowledge and attitudes related to digital health technology to the elderly. In addition, the Facilitating Conditions (FC) refer to the knowledge learning opportunities that may be useful for the elderly in utilizing digital health technology, as well as the hardware facilities and software systems related to digital health technology. These factors can be comprehensively regarded as the external factor dimension, which is the knowledge element in KAP theory.

When studying the element of attitude in KAP theory, we found that there is a variable in UTAUT called Behavioral Intention (BI) that is very similar to the concept of attitude in KAP. This variable mainly refers to the attitude towards implementing digital health behavior, which may be an important link in transforming attitude into final practice. At the same time, in the study of the UTAUT framework, we also observed two important variables, namely Effort

Expectation (EE) and Performance Expectation (PE), which are the perceived usefulness and perceived ease of use of digital health technology mentioned in the classical model, both of which are highly relevant elements of individual attitudes towards digital health literacy. One is the attitude towards whether digital health technology can play a role, and the other is the attitude towards whether individuals can master this technology. These two variables can be considered as core variables in UTAUT. In addition, an important variable discovered in many studies in recent years is Technology Anxiety (TA), which is more related to individual psychological and emotional influencing factors. This is because digital health technology generates individual psychological changes, which tend to be negative. This factor will also have a significant impact on attitudes and belongs to the internal factors of individuals. Based on the characteristics of the four variables mentioned above, in this study, we categorize Technology Anxiety (TA), Effort Expectation (EE), Performance Expectation (PE), and Behavioral Intention (BI) as internal factors that influence digital health technology behavior practices.

This research plan integrates and expands the KAP and UTAUT models, with a logical starting point based on the dual influence of internal and external factors. Based on the characteristics of each variable in the KAP-UTAUT model and the basic principles of the model, it observes the occurrence of digital health technology acceptance and adoption practices in elderly chronic disease patients, as well as the interaction mechanisms between various internal and external factors. Understanding these factors and mechanisms will help to better develop a clear path, understand and optimize the application of digital health technology in the elderly chronic disease population. The extended model constructed for this study is shown in Figure 6.1.

6.3.2 Hypothesis

6.3.2.1 Technology anxiety

Technology Anxiety (TA) is considered a negative emotion related to the use of digital health technology (Meuter et al., 2003). Older adults facing new technology may experience higher levels of anxiety due to declines in physical and cognitive abilities, thereby reducing their willingness to use innovative technology further (Z. Deng et al., 2014). In previous research, technology anxiety has been identified as a significant factor influencing the intention of older adults to adopt mobile healthcare services (Hoque & Sorwar, 2017). Therefore, this study posits the following hypothesis:

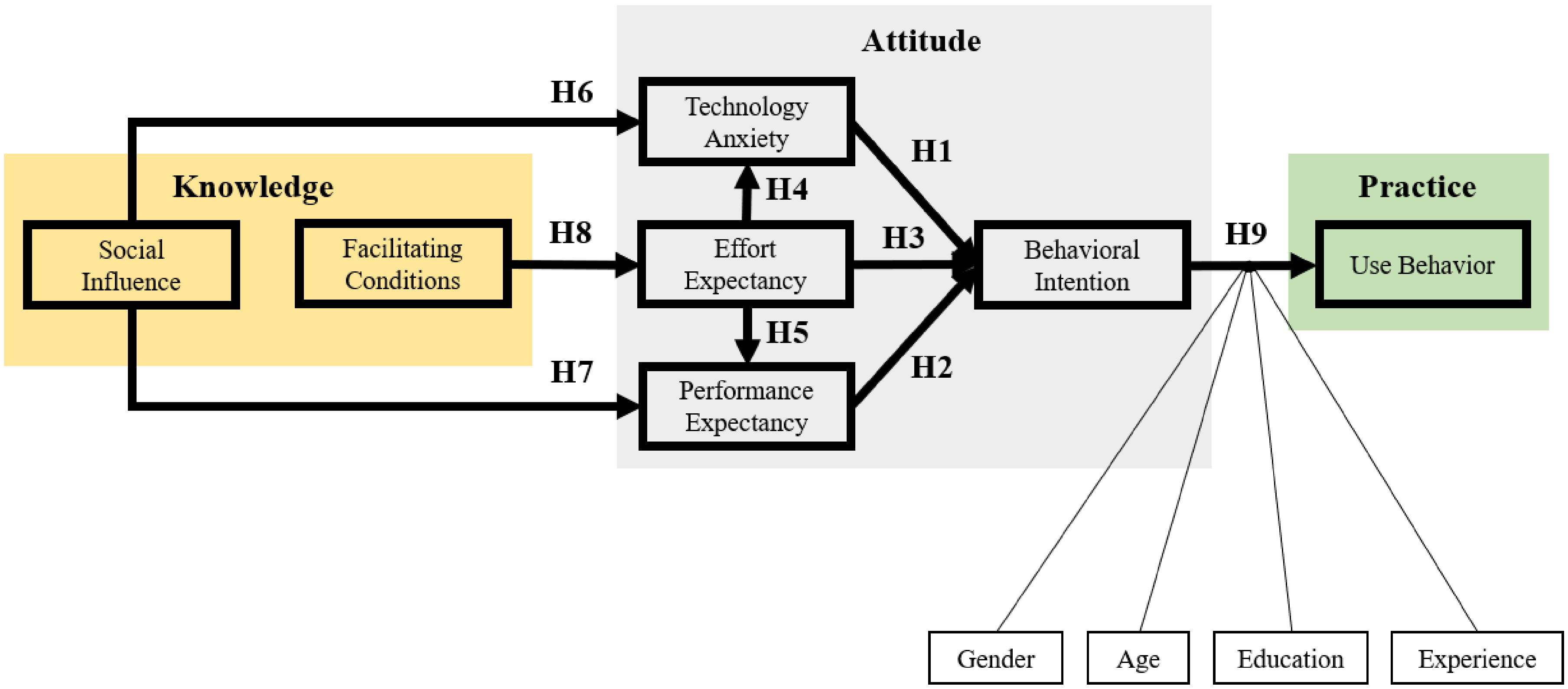

Figure 6.1 KAP-UTAUT extension model

Hypothesis 1 (H1): Technology Anxiety has a negative impact on the behavioural intention to accept and use digital health technology applications.

6.3.2.2 Performance expectancy

Venkatesh et al. pointed out in the Unified Theory of Acceptance and Use of Technology model that Performance Expectancy (PE) is the degree to which an individual believes that using the system will help them progress in their work performance (Venkatesh et al., 2003). In the context of digital healthcare, performance expectancy refers to perceptions of the utility of digital health technology. Much research indicates that performance expectancy significantly influences the intention to use mobile healthcare services (Cao et al., 2022; Hoque & Sorwar, 2017). Therefore, we propose the following hypothesis:

Hypothesis 2 (H2): Performance Expectancy has a positive impact on the behavioural intention to accept and use digital health technology applications.

6.3.2.3 Effort expectancy

Effort Expectancy (EE) is the ease associated with system use, a variable originating from the Unified Theory of Acceptance and Use of Technology model, that considers effort expectancy as an important influencing factor on intention to use (Venkatesh et al., 2003). In this study, effort expectancy represents the ease with which people use digital health technology to manage health. Previous research has confirmed that effort expectancy directly affects the intention to use (Hoque & Sorwar, 2017). It has been indicated that the easier it is for older users to use a new technology, the less anxious they may feel (M. Zhang, 2023). Cimperman et al. (2016) have found that effort expectancy positively influences performance expectancy when it comes to the usage of home telehealth services of older adults. Li et al. (2023) proved that urban older adults' effort expectancy concerning remote health management service has a positive impact on their performance expectancy. Therefore, we have the following hypotheses:

Hypothesis 3 (H3): Effort Expectancy has a positive impact on the behavioural intention to accept and use digital health technology applications.

Hypothesis 4 (H4): Effort Expectancy has a negative impact on the technology anxiety of accepting and using digital health technology applications.

Hypothesis 5 (H5): Effort Expectancy has a positive impact on the performance expectancy to accept and use digital health technology applications.

6.3.2.4 Social influence

Social Influence (SI) is defined as the degree to which an individual believes that other people think they should use the new system (Venkatesh et al., 2003). Previous studies indicate that technology anxiety stems from social cognitive theory, where individuals who perceive themselves as inefficient under the influence of others may experience stress (Z. Deng et al., 2014). In a study on the factors influencing university students' acceptance of mobile healthcare services, Cao et al. (2022) have confirmed that social influence indirectly affects behavioural intentions through performance expectancy. Therefore, we propose the following hypotheses:

Hypothesis 6 (H6): Social Influence has a negative impact on the technology anxiety of accepting and using digital health technology applications.

Hypothesis 7 (H7): Social Influence has a positive impact on the performance expectancy to accept and use digital health technology applications.

6.3.2.5 Facilitating conditions

Facilitating Conditions (FC) in the Unified Theory of Acceptance and Use of Technology are understood as the degree to which an individual believes that organizational and technical infrastructure exists to support system use (Venkatesh et al., 2003). In digital healthcare, facilitating conditions are understood as the extent to which existing digital health infrastructure and conditions support digital health services. A Japanese study has confirmed that facilitating conditions indirectly affect behavioural intentions through effort expectancy (Cao et al., 2022). Therefore, the following hypothesis is proposed:

Hypothesis 8 (H8): Facilitating Conditions have a positive impact on the effort expectancy to accept and use digital health technology applications.

6.3.2.6 Behavioural intention

Behavioral intention (BI) is widely confirmed as a crucial predictive factor for usage behavior in various technology acceptance domains, including the digital healthcare field. Kijsanayotin et al. (2009) demonstrated that behavioral intention is an effective predictor of actual usage behavior. Hoque and Sorwar (2017) revealed in a study conducted in Bangladesh that older adults' intention to use mobile healthcare influences their usage behavior. Similarly, Gu et al. (2021) found that users' behavioral intention in developing countries has a direct and positive impact on the actual usage behavior of electronic health technology. Therefore, we propose also this hypothesis:

Hypothesis 9 (H9): Behavioural intention has a positive impact on the actual usage behaviour to accept and use digital health technology applications.

6.3.2.7 Moderating variables

Demographic variables are crucial in explaining individuals' technology adoption behaviour. Nunes et al. (2019) confirmed that age, gender, and smartphone usage experience partially moderate the acceptance of mobile health applications. Most of the literature focuses on observing the effects of moderating variables on the formation of behavioural intentions and there are already relatively clear conclusions. Gu et al. (2021) made a new attempt to include age, gender, education and experience of use as moderating variables and observed their effects on digital health technology acceptance behaviour. In the classical model of UTAUT, age and experience of use were used as moderating variables, and their effects on the formation of use behaviour through influencing facilitating conditions were also observed. These cases illustrate that in research on UTAUT, attention should also be paid to the effects of moderating variables on the formation of use behaviours, but the literature in this area is still relatively scarce, especially in developing countries and in older chronic disease populations. The present study will analyse the effect of moderating variables on the translation of behavioural intentions into use behaviours, which is an innovation in the design of a study. This study incorporates demographic variables that have been considered in several studies: gender, age, education and experience of use as moderating variables, and observing the role they play in the transformation of intention to use into use behaviour will probably help to further enrich the explanatory power of the model.

6.4 Methodology

6.4.1 Sample size calculations

One of the fundamental issues in partial least squares structural equation modelling (PLS-SEM) is estimating the minimum sample size. A widely used method for minimum sample size estimation is the "10-times rule" (Hair et al., 2011). The "10-times rule" states that the sample size should be at least ten times the number of inner model constructs (Roscoe, 1975). In this study, the questionnaire, which revolves around seven variables, encompasses 28 items. Considering a 20% dropout rate, the required survey sample size should be at least 350.

6.4.2 Participants description

For this study, 1291 questionnaires were distributed across 12 survey institutions, and 1222 valid questionnaires were retrieved, achieving an effective response rate of 94.7%.

Table 6.1 shows the demographic characteristics of the participants. The sample is evenly distributed between male and female participants. All participants are elderly individuals aged 60 and above with at least one chronic disease. The average age of the participants is 70 years, with the majority falling in the range of 65 to 69 years, constituting 26.68% of the sample. Most participants have a high school education, accounting for 42.96%. Additionally, 91.74% have prior experience using digital health applications.

Table 6.1 Demographics of participants (N=1222)

Item	Category	n	%
Gender	Male	611	50%
	Female	611	50%
Age(years)	60-64	277	22.67%
	65-69	326	26.68%
	70-74	280	22.91%
	75-79	173	14.16%
	⩾80	166	13.58%
Chronic disease*	Hypertension	663	54.26%
	Cardiovascular disease	387	31.67%
	Diabetes	453	37.07%
	Stroke	100	8.18%
	COPD	151	12.36%
	Other	53	4.34%
Education	Elementary School or below	107	8.96%
	Junior High School	456	37.32%
	High School	527	43.13%
	University or beyond	132	10.81%
Experience in digital health**	Yes	1121	91.74%
	No	101	8.26%

*Note: The content within the table indicates the listed diseases in the participants' medical history, with many of them having more than one chronic illness.

**Note: The data comes from the actual use experience of digital health in different application scenarios filled in by the respondents.

6.4.3 Questionnaire description – outline

The UTAUT questionnaire used in this study was mainly derived from the scientific literature. As the questionnaire items were all in English, the respondents in the field study were all Chinese elderly chronic patients. Therefore, the research team co-designed the questionnaire's item structure, and two native Chinese-speaking researchers developed the items and sinicized them based on the international questionnaire and the main purpose of this study. Meanwhile, as an important basis for the work, some elements of the findings obtained in the study 2 were also used as important references for the selection and design of the questionnaire, including the three categories of needs, facilitators, and barriers. The items of the UTAUT questionnaire, the sources of the scientific literature, and the categories of references to the findings of the study 2 are shown in Annex G. The research team compared the items of the international questionnaire and the questionnaire used in the present study. The research team compared the items in the international questionnaire with the items in the questionnaire used in this study to ensure that the items dealing with the basic variables of the UTAUT were represented, taking into account, as far as possible, the perspectives of real-world older chronic patients obtained in the study 2, the ability of the respondents to maximize their understanding of each item of the questionnaire, and the clarity and completeness of text and verbal expression in their daily communication with older people. A comparison of the English and Chinese versions of the questionnaire used in this study is shown in Table 6.2 In order to improve the validity of the questionnaire, a pre-survey was conducted among the survey data samplers and a small number of elderly patients to understand whether each question could be understood correctly.

Table 6.2 Questionnaire – in English and Chinese version

Constructs	English Version	Chinese Version
Performance Expectancy	PE1. Digital health applications can be useful in managing my daily health.	PE1. 数字健康技术会有助于我的日常健康管理。
	PE2. Digital health applications can help me receive medical treatment more conveniently.	PE2. 数字健康技术会让我看病就医等医疗服务更方便。
	PE3. Digital health applications can improve my health level and quality of life.	PE3. 数字健康技术会有助于提高健康水平和生活质量。
	PE4. Digital health applications are useless for my health or medical services.	PE4. 数字健康技术对我的健康或医疗服务没有用处。
Effort Expectancy	EE1. It’s easy for me to accept digital health applications.	EE1. 接受数字健康技术这一新生事物对我来说很容易。
	EE2. Learning how to use digital health applications is easy for me.	EE2. 学习数字健康技术及各种应用对我来说很容易。
	EE3. Using digital health applications is easy for me.	EE3. 使用数字健康技术及各种应用对我来说很容易。
	EE4. It's worth learning how to use digital health apps (to help me).	EE4. 学习如何使用数字健康应用程序对我有价值和有帮助。
Social Influence	SI1. Family members or relatives influence me to use digital health apps.	SI1. 家人或亲戚会影响我使用数字健康技术。
	SI2. Teachers and colleagues influence me to use digital health applications.	SI2. 老师和同事会影响我使用数字健康技术。
	SI3. Friends (or fellow patients) influence me to use digital health applications.	SI3. 朋友（或病友）会影响我使用数字健康技术。
	SI4. Medical staff influence me to use digital health applications.	SI4. 医务人员会影响我使用数字健康技术。
Facilitating Conditions	FC1. I have the knowledge necessary to use digital health	FC1. 我拥有使用数字健康技术所需的知识。

	applications.	
	FC2. When I have difficulties using various digital health applications, I can get help from others.	FC2. 当我使用数字健康技术及各种应用遇到困难时，可以得到别人的帮助。
	FC3. When using digital health applications, I have access to various resources to support me (software, network, equipment, hardware environmental conditions, etc.).	FC3. 使用数字健康技术时，我可以获得各种资源支持（软件、网络、设备、硬件环境条件等）。
	FC4. The use of digital health applications does not contradict my use of other technologies, functions, services, needs, etc.	FC4. 使用数字健康技术和各种应用，与我使用其他技术、功能、服务、需求等不矛盾。
Technology Anxiety	TA1. Using digital health applications may make me feel uneasy and confused.	TA1.我不习惯和无法适应使用数字健康技术及各种应用。
	TA2. Using digital health applications would make me very nervous.	TA2. 使用数字健康技术及各种应用，让我感到压力和紧张。
	TA3. Using digital health applications may make me feel uncomfortable.	TA3. 使用数字健康技术及各种应用，会让我感到各种不放心。
	TA4. I feel calm to use digital health applications.	TA4. 我能很好信赖数字健康技术及各种应用。
Behavioral Intention	BI1. I plan to use digital health applications frequently.	BI1. 我打算经常使用数字健康技术及各种应用。
	BI2. I'm willing to recommend digital health applications to others.	BI2. 我愿意向他人推荐数字健康技术及各种应用。
	BI3. I don't intend to use digital health applications for the next six months.	BI3. 我不打算在接下来六个月使用数字健康技术及各种应用。
	BI4. I intend to use (more) digital health applications as soon as possible.	BI4. 我打算尽快使用（更多）数字健康应用程序。
User Behaviour	UB1. I have used digital health technology and various applications.	UB1. 我使用过数字健康技术及各种应用。
	UB2. Using digital health applications is a pleasant experience.	UB2. 使用数字健康技术和各种应用，会给我带来愉快的体验经历。
	UB3. When I need to seek healthcare service, digital health applications will be very important options for me.	UB3. 当我需要寻求医疗健康服务时，数字健康技术和各种应用将是我非常重要的选择。
	UB4. Using digital health applications helps me to manage my self-care (for my health).	UB4. 数字健康应用程序可以帮助我开展自我健康管理。

6.4.4 Inclusion criteria and exclusion criteria

Inclusion Criteria:

(1) Age 60 years and above;

(2) According to the International Classification of Diseases, 10th Revision (ICD-10) diagnostic criteria for chronic diseases, this study mainly collected data from elderly patients with five specific chronic diseases: essential (primary) hypertension (I10.x00), type 2 diabetes (E11.900), coronary atherosclerotic heart disease (I25.103), stroke (I64.x00), and chronic obstructive pulmonary disease (J44.900);

(3) Patients capable of independent judgment and understanding, able to complete the questionnaire;

(4) Residing in Shanghai for six months or more;

(5) Voluntary participation in this research.

Exclusion Criteria:

(1) Critically ill emergency patients;

(2) Patients involved in medical disputes.

6.4.5 Data processing techniques and analysis

6.4.5.1 Statistical analysis

This study represented count data as rates or composition ratios, and measurement data were expressed as mean ± standard deviation. SPSS 26.0 (IBM Corp.) was employed for conducting chi-square tests, t-tests, or one-way analysis of variance. SmartPLS (v4.0.9.5) was used to perform validation analyses on theoretical hypotheses, reliability, and validity within the structural equation model.

6.4.5.2 Structural equation model

Structural Equation Modelling (SEM) integrates various statistical analysis models such as multivariate regression, factor analysis, and path analysis. It primarily explores the statistical relationships between observed variables and latent variables, as well as the relationships among latent variables (Jöreskog & Sörbom, 1982).

The method is essentially a tool that relies on variable covariance matrices to explore complex causal associations among different variables, is suitable for dealing with simultaneous analyses of multiple dependent variables and can accurately reveal the inherent causal structure between latent and observable variables. In this context, observable variables are those that can be directly measured by quantitative means, while latent variables are those abstract conceptual variables that are not directly observable but can be indirectly reflected by theoretical derivation or other variables. SEM expresses theoretical hypotheses about the relationships between variables in a path diagram, illustrating visible causal relationships and the degree of interrelation among multiple dependent variables. It also facilitates the measurement of dependent variables (Ullman & Bentler, 2012).

SmartPLS (v.4.0.9.5) software was employed to test and analyse the structural equation model – according to the conceptual model we propose. SmartPLS is commonly used for analysing structural equation data, particularly for conducting Partial Least Squares Structural Equation Modelling (PLS-SEM) tests on hypothesis relationships between study models and multivariate data (Hair et al., 2022). Compared with other SEM applications (such as SPSS AMOS, Mplus, etc.), SmartPLS has been continuously updated and optimized in recent years. In addition to meeting the needs of data analysis, SmartPLS also has a more user-friendly and intuitive graphical interface, which makes it widely adopted in similar studies (Cao et al., 2022; Gu et al., 2021; Hoque & Sorwar, 2017).

Data collected from the questionnaire were imported into Excel and then into SmartPLS. The bootstrap method was used to calculate path coefficients and their significance. To ensure result stability and replicability, this study employed 5000 random subsamples (Cao et al., 2022).

The structural equation model can be divided into a measurement model and a structural model. The measurement model primarily investigates the relationships between latent variables and indicators, known as factor analysis. The specific mathematical model is represented as follows:

$$X=\Lambda_x\xi+\delta$$
$$Y=\Lambda_y\eta+\varepsilon$$

Within the Structural Equation Modelling (SEM) context, the model involves exogenous vector X and endogenous vector Y. Here, ξ represents exogenous latent variables, and η denotes endogenous latent variables. The factor loading matrices for exogenous indicator X on exogenous latent variable ξ are denoted as Λx, and for endogenous indicator Y on endogenous latent variable η, they are denoted as Λy. δ and ε represent errors in measuring X and Y, respectively. These errors signify the portions that cannot be explained by latent variables (Ullman & Bentler, 2012).

The structural model, also known as regression analysis, is primarily employed to study the matrix relationships between latent variables. The specific mathematical model is expressed as follows:

$$\eta=\beta\eta+\Gamma\zeta+\zeta \quad (7.4)$$

Here, η represents endogenous latent variables, and ξ represents exogenous latent variables.

β signifies the relationships between endogenous latent variables, Γ denotes the impact of exogenous variables on endogenous variables, and ζ is the residual vector representing the portion within the model that remains unexplained (Ullman & Bentler, 2012).

6.4.5.3 Reliability and validity analysis

We developed the questionnaire based on the fundamental variables of the theoretical model, potential extended variables, and well-established classical questionnaires previously utilized (Akdur et al., 2020; Cao et al., 2022; W. Li et al., 2023; Patil et al., 2020; Zhou et al., 2021).

Integrating the design philosophy of this study, the questionnaire was crafted, incorporating three reverse questions to assess the reliability of the survey results. At the initiation of the survey, a subset of the sample was employed to examine the reliability and validity of the questionnaire. Subsequent adjustments to the structure and content of the questionnaire were made based on the reliability and validity analysis results.

Reliability is an indicator used to assess the degree of variability of measurement results due to random errors in the measurement process, and its core purpose is to test the stability, consistency, and precision of the measurement tool (Joe, 1993). Cronbach's alpha coefficient (α) is a commonly used index to examine internal consistency. When the value of the α coefficient is > 0.8, it indicates high-scale reliability. If the α coefficient is < 0.6, a scale revision should be considered. An α coefficient > 0.7 is the minimum acceptable value for scale reliability (Peterson & Kim, 2013).

Composite Reliability (CR) is computed based on the factor loading values of each indicator. Composite reliability is used to assess the consistency of the measures associated with each latent variable. Higher values of combined reliability mean that the measures involved in the latent variable are more strongly correlated with each other and show a high degree of consistency; conversely, if the combined reliability is low, the degree of consistency is low (Peterson & Kim, 2013). The specific mathematical model is expressed as follows:

$$\rho_c = CR = (\Sigma\lambda)^2 / [(\Sigma\lambda)^2 + \Sigma(\theta)]$$

Within this context, ρ_c represents composite reliability, λ denotes the standardized parameter estimate (factor loading) of the indicator variable on the latent variable, and θ corresponds to the error variance of the indicator variable (i.e., the variability of ε or θ).

Average Variance Extracted (AVE) serves as an indicator of structural validity, reflecting the convergent validity. reflects the degree of indicator variable variation that the latent variable construct can explain relative to the amount of measurement error variance. Thus, the deeper the latent variable constructs can explain the variance in the indicator variables, the more significant their average variance extraction is, indicating a high degree of convergent validity and accuracy of the measurement instrument. Generally, when AVE > 0.5, it suggests a high level of convergent validity. The specific mathematical model is expressed as follows:

$$\rho_v = AVE = (\Sigma\lambda^2)/[(\Sigma\lambda^2) + \Sigma(\theta)] \quad (7.6)$$

The counterpart to convergent validity is discriminant validity, which reflects the degree of differentiation between latent variables. This indicator is primarily assessed through three methods. Firstly, the confidence interval estimation method for correlation coefficients is employed. If the 95% confidence interval of the correlation coefficient between two latent variables includes 1, it indicates poor discriminant validity. Conversely, if the correlation coefficient between two latent variables is significantly below 1, it suggests good discriminant validity.

The second approach is the competitive model comparison method. Two confirmatory factor analysis models are established. In one model, the relationships between latent variables are freely estimated, while in the other, these relationships are constrained to 1. If the former does not significantly outperform the latter, it suggests a lack of discriminative power between the two latent variables.

The third method is the Average Variance Extracted (AVE) comparison. If the square root of AVE is greater than the correlation coefficient between each pair of latent variables, or if AVE is greater than the square of the correlation coefficient between the two latent variables, it indicates good discriminant validity between these latent variables (Fornell & Larcker, 1981).

6.4.6 Procedure

From July 2023 onwards, this study conducted a two-month patient survey in 12 medical institutions, distributed across six administrative districts in Shanghai, they are Pu Dong New District, Yang Pu District, Hong Kou District, Jing An District, Huang Pu District, and Xu Hui District. Among the 12 surveyed medical institutions, 6 are tertiary hospitals, 3 are secondary hospitals, and 3 are community health service centers.

The locations for investigation in tertiary and secondary hospitals are the inpatient wards of these hospitals that receive and treat diseases related to the study of the root cause; The survey location of the community health service centre is the outpatient department of the centre. The medical institutions located in Pu Dong New District include East Hospital and Zhou Pu Hospital. Ease Hospital is a tertiary hospital (with 101 respondents), while Zhou Pu Hospital is a secondary hospital (with 100 respondents). Xin Hua Hospital is located in Yang Pu District and is a tertiary hospital (with a survey of 103 people). The First People's Hospital is located in Hong Kou District and is a tertiary hospital (with a survey population of 100 people). The Central Hospital of Jing An District is located in Jing An District and is a secondary hospital (with 103 people surveyed). The Sixth People's Hospital is located in Xu Hui District and is a tertiary hospital (with a survey of 104 people). The central urban area of Shanghai in Huang Pu District is also a densely populated area with an elderly population. In this area, we surveyed six medical institutions, including two tertiary hospitals (Rui Jin Hospital and Ninth People's Hospital, both of which had 102 respondents), one secondary hospital (Huang Pu District Central Hospital, also known as Ninth People's Hospital Huang Pu Branch, with 102 respondents), and three community health service centers, namely Da Pu Qiao Community Health Service Center (with 101 respondents), Xiao Dong Men Community Health Service Center (with 102 respondents), and Ban Song Yuan Community Health Service Center (with 102 respondents).The survey locations in tertiary and secondary hospitals were in the inpatient wards treating the diseases relevant to this study. In community health service centers, the survey locations were outpatient departments. Among the 12 surveyed medical institutions, six are tertiary hospitals, three are secondary hospitals, and three are community health service centers.

The research institutions involved, and their geographical distribution are presented in Figure 6.2.

During the survey period, all elderly patients with eligible diseases treated at the locations were approached to inquire about their willingness to participate in the investigation. For all eligible and voluntarily participating elderly patients in this trial, a questionnaire survey was conducted.

Trained investigators assisted each participating patient in completing the survey questionnaire, and the survey results were directly entered online using mobile phones and electronic questionnaires.

The research team provided three rounds of training for eight investigators, covering the following topics: (1) clarifying the survey theme and core concepts; (2) becoming familiar with the survey content of each section of the questionnaire; and (3) mastering the methods of introducing the survey and initiating questions. Volunteers conducted the surveys in the target units after training.

The research team developed an electronic questionnaire to collect participants' survey answers more quickly and efficiently. The electronic questionnaire is shown in Table 6.3 and the interface of the electronic questionnaire is presented in Figure 6.3.

Before formally asking questions, each researcher, regarding the instructional legend, as shown in Annex H, provided examples to the interviewed patients to introduce scenarios of digital health technology and applications, clarifying the research theme and key concepts. Due to visual impairment and less nimble finger movements in the elderly population, surveyors read each question to the interviewees individually and, based on their responses, assisted them in selecting the corresponding options on the electronic questionnaire.

Most questions in the questionnaire used Likert scales to define patients' opinions. To enhance the reliability and efficiency of the survey, the research team used a five-point scale ruler during on-site surveys (see Annex I). This allowed participants to indicate the scale consistent with their subjective perceptions before entering the electronic questionnaire, ensuring the accuracy of subjective data collection.

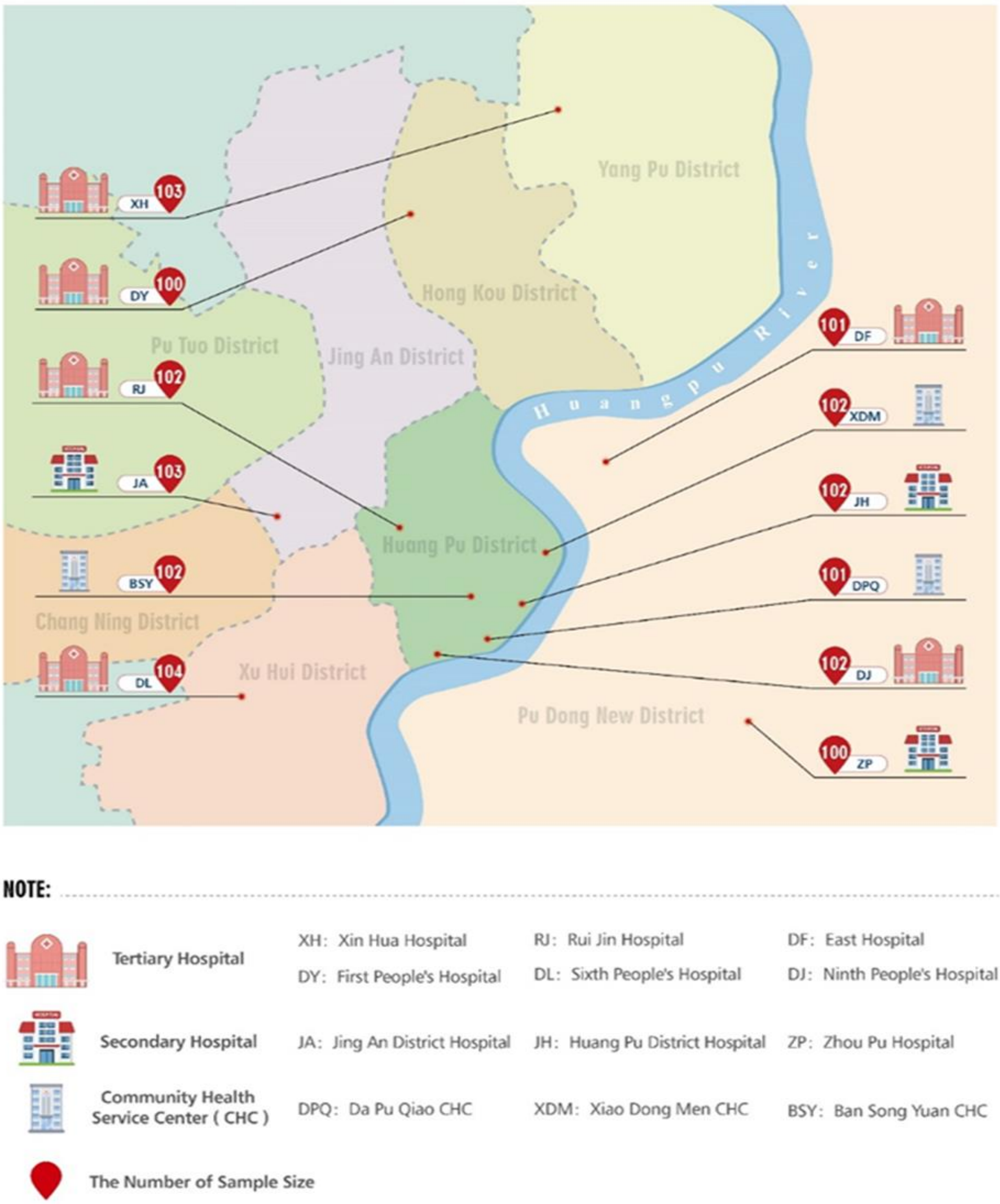

Figure 6.2 The geographical distribution of surveyed participants' medical institutions

Table 6.3 Electronic questionnaire

Items		Options
Basic personal information		
Hospital name：__________		
Date of Birth：_______year/___month/___day		
Phone number：______________		
Gender		Male
		Female
Diagnosed chronic diseases		High blood pressure
		Coronary heart disease
		Diabetes
		Stroke
		Chronic Obstructive Pulmonary Disease (COPD)
		Other_______
Education level		Elementary school or below
		Junior High School
		High School
		University or beyond
Experience in using digital health technologies		
Your experience with digital health technology:		Yes
		No
For the following digital health applications, you have		used them independently
Health QR Code		used them with the help of family members
Electronic health record		never used them
Electronic report		
Electronic discharge summary		
Telemedicine service		
Telesurgery		
Outpatient appointment		
Mobile health management applications		
Smart wearable devices		
(If you have used digital health technology independently) Which of the above digital health technologies, do you use most frequently?		Online appointment
		View electronic reports
		Mobile e-payment
		Remote medical consultation
		Smart wearable devices to monitor physical condition
(If you have not used digital health independently) Which of the above digital health technologies, are you most familiar with?		Online appointment
		View electronic reports
		Mobile e-payment
		Remote medical consultation
		Smart wearable devices to monitor physical condition
Apply a five-point Likert scale to the following questions		
Performance Expectancy	PE1. Digital health applications can be useful in managing my daily health.	Strongly Disagree
	PE2. Digital health applications can help me receive medical treatment more conveniently.	Disagree
	PE3. Digital health applications can improve my health level and quality of life.	Neither disagree nor agree
	PE4. Digital health applications are useless for my health or medical services.	Agree

Effort Expectancy	EE1. It's easy for me to accept digital health applications. EE2. Learning how to use digital health applications is easy for me. EE3. Using digital health applications is easy for me. EE4. It's worth learning how to use digital health apps (to help me).	Strongly Agree
Social Influence	SI1. Family members or relatives influence me to use digital health apps. SI2. Teachers and colleagues influence me to use digital health applications. SI3. Friends (or fellow patients) influence me to use digital health applications. SI4. Medical staff influence me to use digital health applications.	
Facilitating Conditions	FC1. I have the knowledge necessary to use digital health applications. FC2. When I have difficulties using various digital health applications, I can get help from others. FC3. When using digital health applications, I have access to various resources to support me (software, network, equipment, hardware environmental conditions, etc.). FC4. The use of digital health applications does not contradict my use of other technologies, functions, services, needs, etc.	
Technology Anxiety	TA1. Using digital health applications may make me feel uneasy and confused. TA2. Using digital health applications would make me very nervous. TA3. Using digital health applications may make me feel uncomfortable. TA4. I feel calm to use digital health applications.	
Behavioural Intention	BI1. I plan to use digital health applications frequently. BI2. I'm willing to recommend digital health applications to others. BI3. I don't intend to use digital health applications for the next six months. BI4. I intend to use (more) digital health applications as soon as possible.	
User Behaviour	UB1. I have used digital health technology and various applications. UB2. Using digital health applications is a pleasant experience. UB3. When I need to seek healthcare service, digital health applications will be very important options for me. UB4. Using digital health applications helps me to manage my self-care (for my health).	

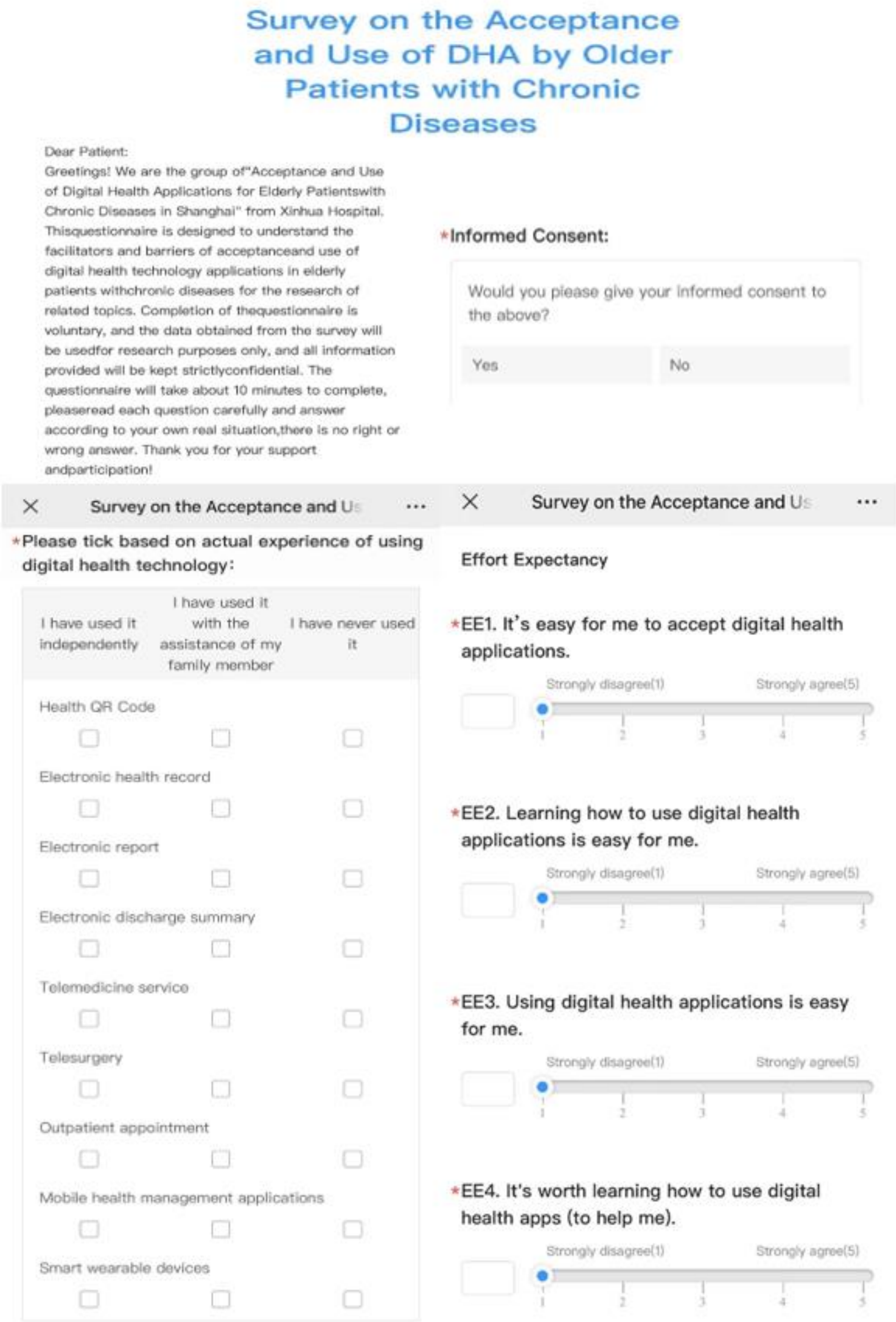

Figure 6.3 Electronic questionnaire interface

6.5 Results

6.5.1 Analysis of reliability and validity of data

Before delving into the results of the structural equation analysis, a comprehensive assessment of the questionnaire survey's quality was conducted by systematically evaluating convergent validity and internal reliability.

Internal reliability was measured using Composite Reliability and Cronbach's Alpha, with a threshold exceeding 0.7, indicating satisfactory internal consistency (Peterson & Kim, 2013). To ensure convergent validity, an evaluation was performed on AVE (Average Variance Extracted) and item loadings. If AVE is greater than 0.5 and loadings exceed 0.7, structural validity meets the required standards (Petter et al., 2007). The present study showed an AVE of 0.487 for FC and loadings for FC2, FC3 and FC4, with the above data below the threshold. Our analysis of the frequency distribution of scores for the four FC questions revealed that the FC1 curve characteristics differed from FC2, FC3 and FC4, with about half of the older adults having little or no knowledge of digital health. However, as reflected in the other three question items, the older adult group showed good support for getting help from others, getting support from resources, and not having ambivalence about the use of new technology (see Annex J). This is consistent with the findings obtained from the focus group in study 2. The survey showed that there were significant differences in the knowledge of digital health among the Chinese elderly population with chronic diseases, with some being more familiar but others having no knowledge of digital health. Currently, elderly people are highly dependent on the help of others to use new technologies, and their use of new technologies is also dependent on the support of external resources. Therefore, although the loading value of FC1 performs better, based on the actual current situation known from the survey, there is a paradoxical conflict between FC1 and the other three question items that are also used as measurement items for the FC latent variable. The primary reference literature as a source of FC question item design does validate that digital health technology knowledge is an important measure of FC latent variables, but the literature also notes differences in the effect of FC on behavioral intention across different groups (Cao et al., 2022). Quaosar et al. (2018) found that FC did not have an impact on behavioral intentions towards digital health technology in the older population. Cao et al. (2022) focus on a younger population in developed countries, which differed significantly in many characteristics from the present study population of older chronically ill patients in developing countries. In addition, the results of this study also showed a large difference in the perceived digital health knowledge of the investigated elderly chronic disease population. For these reasons, we ultimately removed the FC1 item from the structural equation. Table 6.4 shows the reliability and validity results for the latent variable "facilitating conditions" before FC1 was excluded and after only FC2, FC3 and FC4 items were included in the structural equation. As shown in the table, after the exclusion of FC1, the CR ranged from 0.791 to 0.969, the Cronbach's alpha ranged from 0.755 to 0.969, which is higher than the recommended value of 0.7, which means that the internal reliability is at a desirable level, and the AVE ranged from 0.665 to 0.942, which is higher than the standardised value of 0.5. The loadings of all the items were higher than 0.7, which means that the construct validity is at a desirable level. effectiveness is at a desirable level. Above 0.7, it means that the structural validity is performing well.

Our study assessed discriminant validity of the structural equation model through the square root of AVE and the cross-loading matrix. If the square root of AVE for each construct is greater than the correlation coefficient between constructs, it suggests ideal discriminant validity (Hair et al., 2022). Specifically, the square root of AVE for each construct should be greater than the correlation coefficient between constructs on the diagonal and off-diagonal elements (Fornell & Larcker, 1981).

The results in Table 6.5 show that the model in this study exhibits excellent discriminant validity.

6.5.2 Validation of structural equation model hypothesis

Figure 6.4 displays the results of the structural equation model, and Table 6.6 summarizes the hypothesis testing outcomes. The results indicate that all eight hypotheses in this study are supported. TA has a significant negative impact on BI, EE negatively influences TA; FC has a significantly positive effect on EE, SI and EE have significant positive effects on PE; EE and PE have significant positive effects on BI, and BI has a significant positive impact on UB. SI does not have a statistically significant impact on TA in this study, indicating that Hypothesis 6 is not supported. Regarding moderating factors, gender, age, and experience influence the transformation from BI to UB concerning the acceptance and use of digital health applications, and these moderating effects are statistically significant.

Table 6.4 The measurement model before and after removing non-conforming items (N=1222)

Items	Before				After			
	Loadings	AVE	CR	Cronbach's alpha	Loadings	AVE	CR	Cronbach's alpha
BI1	0.952				0.952			
BI2	0.836	0.833	0.937	0.898	0.836	0.833	0.937	0.898
BI4	0.945				0.945			

EE1	0.892				0.893			
EE2	0.946	0.840	0.955	0.936	0.945	0.840	0.955	0.936
EE3	0.950				0.948			
EE4	0.878				0.879			
FC1	0.872				-			
FC2	0.584	0.487	0.787	0.727	0.794	0.665	0.856	0.755
FC3	0.604				0.804			
FC4	0.695				0.848			
PE1	0.965				0.965			
PE2	0.971	0.942	0.980	0.969	0.971	0.942	0.980	0.969
PE3	0.976				0.976			
SI1	0.796				0.796			
SI2	0.911	0.784	0.935	0.909	0.911	0.784	0.935	0.909
SI3	0.925				0.925			
SI4	0.905				0.905			
TA1	0.931				0.931			
TA2	0.959	0.878	0.956	0.931	0.959	0.878	0.956	0.931
TA3	0.921				0.921			
UB1	0.877				0.878			
UB2	0.942	0.846	0.956	0.939	0.942	0.846	0.956	0.939
UB3	0.925				0.925			
UB4	0.933				0.933			

Table 6.5 Correlation matrix and square root of the AVE after removing non-conforming items (N=1222)

	BI	EE	FC	PE	SI	TA	UB
BI	**0.913**						
EE	0.824	**0.917**					
FC	0.357	0.350	**0.815**				
PE	0.666	0.654	0.374	**0.971**			
SI	0.172	0.223	0.223	0.310	**0.885**		
TA	0.731	0.752	0.350	0.566	0.155	**0.937**	
UB	0.758	0.725	0.478	0.816	0.374	0.606	**0.920**

Males, relatively younger elderly individuals, and participants with experience in digital health usage, are more likely to translate the intention to use digital health applications into actual usage behavior. The educational level of the participants did not show a moderating effect on the transformation from BI to UB in the acceptance and use of digital health applications.

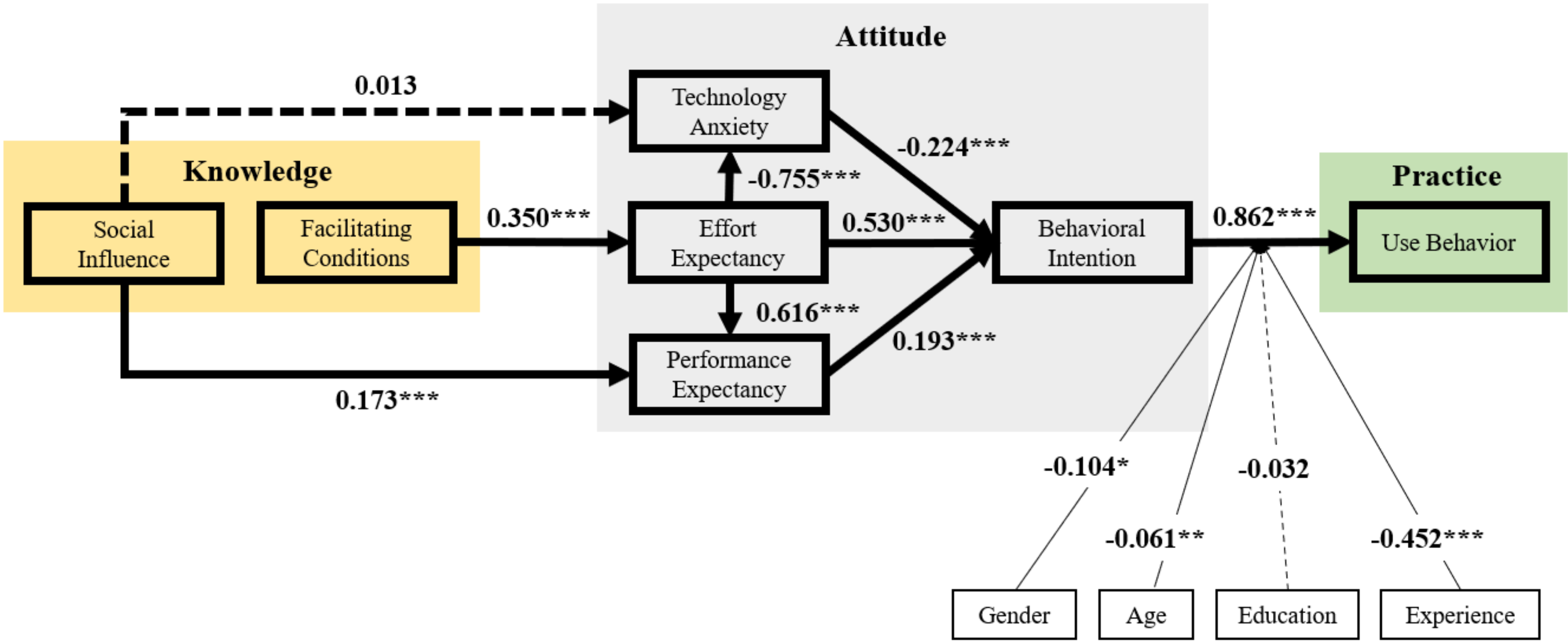

Figure 6.4 Validated model according to the conceptual model proposed

Notes:
1. *, **, *** refers to significance level at p<0.05, p<0.01, p<0.001, respectively.
2. Gender is a dichotomous variable, where 1 represents males and 2 represents females. Age is set as a tri-categorical variable, where 1 represented 60-69 years, 2 represented 70-79 years, and 3 represented 80 years or older. Education is set as a four-categorical variable, where 1 represents primary school, 2 represents junior high school, 3 presents high school, and 4 represents the university or beyond. Experience is a dichotomous categorical variable, where one represents having experience with digital health applications, and 2 represents no experience.

Table 6.6 Results of the hypothesis test (N=1222)

Hypothesis	Path	β	p-value	Hypotheses
H1	TA → BI	-0.224	0.000	Supported
H2	PE → BI	0.193	0.000	Supported
H3	EE → BI	0.530	0.000	Supported
H4	EE → TA	-0.755	0.000	Supported
H5	EE → PE	0.616	0.000	Supported
H6	SI → TA	0.013	0.532	Not Supported
H7	SI → PE	0.173	0.000	Supported
H8	FC → EE	0.350	0.000	Supported
H9	BI→UB	0.862	0.000	Supported

6.5.3 Results of participants' utilization of digital health applications

The vast majority of participants (91.74%) have utilized the Health QR Code, a mobile application employed in mainland China for assessing individual health status during the prevention and control of COVID-19 virus transmission (Zou & Di, 2023).

Approximately 60% of participants have experience viewing electronic medical histories or reports, while about 40% have yet to engage with these functionalities. Around 20% to 30% of participants, independently or with family assistance, have accessed electronic discharge summaries. Most participants (98.28%) have not experienced remote medical services, and none have undergone remote surgeries. Approximately 85% of participants have engaged in online appointment scheduling (either independently or with family assistance); 65% of participants have never used health management mobile apps. The proportion of participants independently using smart wearable devices is 37.73%, and 53.85% of participants have never encountered smart wearable devices, as illustrated in Figure 6.5 and Figure 6.6.

6.5.4 Analysis based on demographics and UTAUT variables

Gu et al. (2021) confirmed that gender, age, education level and usage experience have an impact on users' willingness and behavior to use eHealth technology.

In this study, SPSS 26 software was employed to analyze participants with different ages, genders, education levels, and varying experiences in the use of digital health applications concerning intention and behavior. The statistical significance was assessed using the chi-square test, as detailed in Table 6.7 and Table 6.8.

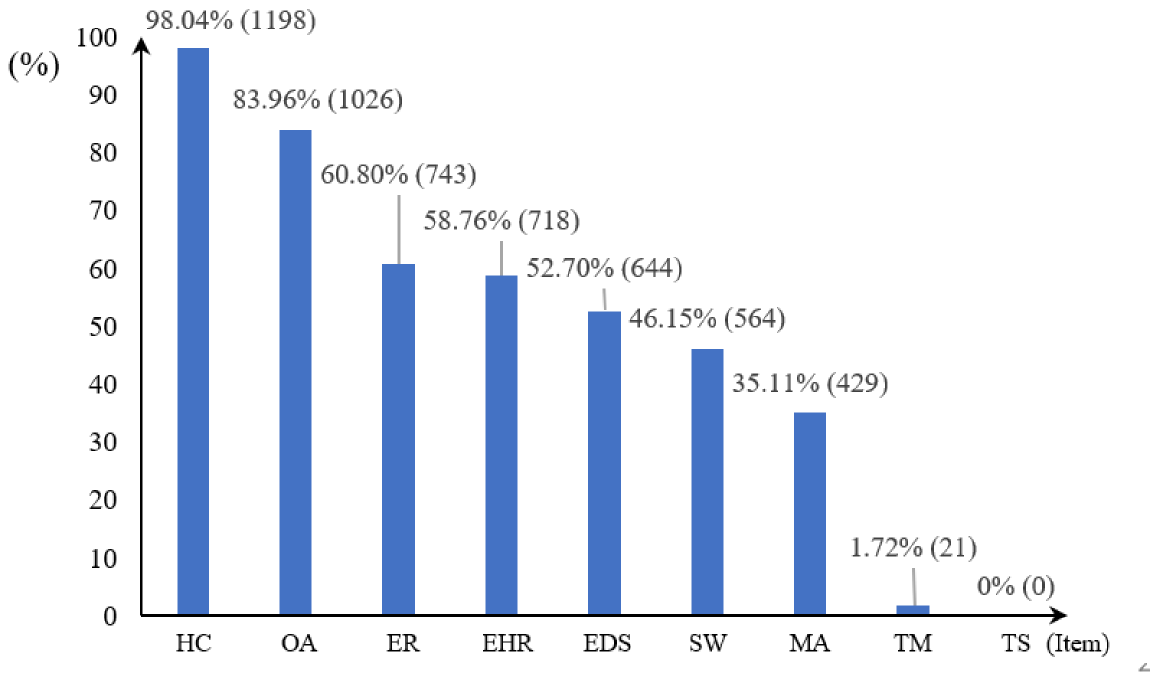

Figure 6.5 Proportion and values of participants using digital health applications (DHA) (N=1222)

Notes. HC: Health QR Code, OA: Outpatient appointment, ER: Electronic report, EHR: Electronic health record, EDS: Electronic discharge summary, SW: Smart wearable devices, MA: Mobile health management applications, TM: Telemedicine service, TS: Telesurgery.

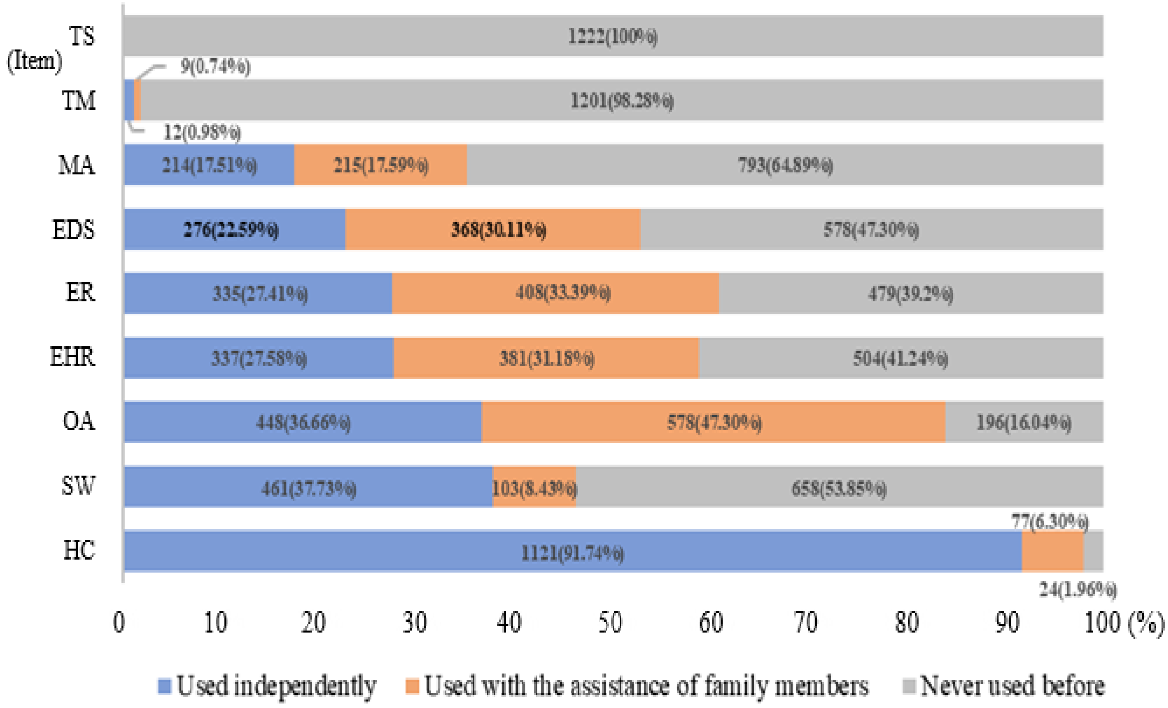

Figure 6.6 Characteristics of participants using digital health applications (DHA) (N=1222)

Notes. HC: Health QR Code, SW: Smart wearable devices, OA: Outpatient appointment, EHR: Electronic health record, ER: Electronic report, EDS: Electronic discharge summary, MA: Mobile health management applications, TM: Telemedicine service, TS: Telesurgery.

Table 6.7 Demographic factors and structural equation variables (BI and UB)

Item	Category	BI			P value	UB			P value
		A	B	C		A	B	C	
Gender	Male	800	91	942	0.359	654	237	1553	0.634
	Female	833	100	900		632	253	1559	
Age	60-69	730	87	992	0.000	600	220	1592	0.018
	70-79	645	80	634		506	198	1108	
	≥80	258	24	216		180	72	412	
Education	Elementary school or below	215	22	84	0.000	219	45	164	0.000
	Junior high school	707	72	589		510	205	1109	
	High school	625	76	880		517	216	1375	
	University or beyond	86	21	289		40	24	464	
Experience in DH	Yes	931	167	1653	0.000	683	328	2657	0.000
	No	702	24	189		603	162	455	

Notes.1. A: Disagree or Strongly disagree, B: Neither Agree nor Disagree, C: Agree or Strongly agree. The BI section consists of 3 items, BI1, BI2 and BI4; the UB section consists of 4 items, UB1-UB4.
2. The numbers in columns A, B, and C represent the number of participants.
3. DH stands for Digital Health

Table 6.8 Demographic factors and structural equation variables (EE, PE and TA)

Item	Category	EE			P value	PE			P value	TA			P value
		A	B	C		A	B	C		A	B	C	
Gender	Male	934	246	1264	0.000	358	116	1359	0.952	1045	134	654	0.013
	Female	1074	206	1164		353	113	1367		972	121	740	
Age	60-69	793	223	1396	0.000	330	114	1365	0.260	1114	133	562	0.000
	70-79	831	184	797		279	91	989		679	98	582	
	≥80	384	45	235		102	24	372		224	24	250	
Education	Elementary school or below	277	39	112	0.000	127	20	174	0.000	138	25	158	0.000
	Junior high school	804	183	837		329	103	936		683	106	579	
	High school	862	196	1050		240	95	1246		891	102	588	
	University or beyond	65	34	429		15	11	370		305	22	69	
Experience in DH	Yes	1045	349	2274	0.000	422	150	2179	0.000	1766	191	794	0.000
	No	963	103	154		289	79	547		251	64	600	

Notes.1. A: Disagree or Strongly disagree, B: Neither Agree nor Disagree, C: Agree or Strongly agree. The EE section consists of 4 items, EE1-EE4; the PE section consists of 3 items, PE1-PE3; the TA section consists of 3 items, TA1-TA3.
2. The numbers in columns A, B, and C represent the number of participants.
3. DH stands for Digital Health.

As shown in Table 6.7 and 6.8, among the elderly population, relatively younger participants have higher education levels, possess prior experience with digital health applications, and demonstrate a stronger willingness to use new technology. They also tend to convert this willingness into actual usage behavior. Additionally, males, those who are relatively younger, have higher education levels and prior usage experience and perceive learning and using digital health applications to be easier. Participants with higher education levels and prior usage experience express a more positive evaluation of the benefits associated with digital health applications. On the other hand, females, those older, with lower education levels, and without usage experience, are more likely to experience anxiety when using digital health applications.

6.6 Brief conclusions of study 3

Based on the proposed KAP-UTAUT theoretical model, we collected data through a questionnaire to test the hypotheses and explore the factors affecting the acceptance and use of digital health technologies and their applications among elderly chronic disease patients. The results of the reliability test confirmed that the questionnaire had an ideal reliability, thus validating our conceptual model. The results of the hypothesis testing of structural equation modelling helps to explain the acceptance and use of digital health technologies by elderly chronic disease patients. According to the findings, technology anxiety had a significant negative impact on behavioral intention; effort expectancy and performance expectancy had a significant positive impact on behavioral intention; effort expectancy had a negative impact on technology anxiety; facilitating conditions had a significant positive impact on effort expectancy; social influence and effort expectancy had a significant positive impact on performance expectancy; and behavioral intention had a significant positive influence on use behavior. In contrast, we did not find a statistically significant effect of social influence on technology anxiety.

This study also focused on the current use of digital health applications by older patients with chronic diseases, and the three digital health applications that participants would be most familiar with (with the highest percentage of use independently or with the assistance of family members) were health QR codes, online appointment, and electronic report.

Regarding demographics and moderating factors, we observed that older participants who were male, relatively younger and had experience in using digital health applications, were more likely to have a stronger intention to use digital health applications and more inclined to convert their intention into user behaviors.

Through study 3, we propose and validate a conceptual model to explain the acceptance and use of digital health technologies by elderly chronic disease patients, identify the factors that affect their behaviors, and propose suggestions to facilitate the adoption of digital health technologies by older patients with chronic diseases.

Chapter 7: Research Discussion

7.1 Model influencing pathway

This section comprehensively discusses the results based on the documental study, focus group discussions, and the inferential study – considering the findings from the theoretical model analysis and validation.

In the model analysis, it was found that performance expectancy, effort expectancy, and technology anxiety significantly influence the behavioral intention of elderly patients with chronic diseases to adopt digital health technologies – in other words, the greater the expectation for the performance and effort made and the lower the anxiety regarding the use of technology, the stronger the intention of these patients to adopt digital health technologies.

Firstly, effort expectancy positively influences behavioral intention, with a very high impact path coefficient ($\beta=0.529$, $p<0.001$), consistent with findings in related studies (Gu et al., 2021; Tian & Wu, 2022). Elderly individuals are willing to learn or sustain the use of new technologies only when they perceive digital health technologies as easy to use (Jiang et al., 2022). This aligns with the qualitative research results, where participants expressed an expectation for the simplification of digital health technology operations. Thus, developers of digital health applications should fully consider the needs of elderly users, and age-appropriate product design will enhance the willingness of the elderly to use relevant functionalities and products.

Secondly, performance expectancy in the model has a positive impact on behavioral intention, consistent with the results of several studies (Y. Liu et al., 2022; Philippi et al., 2021). When elderly patients perceive the benefits and support of digital health technology for self-health management, they are more likely to continue using this technological application in the future (Van middelaar et al., 2018). The results of focus group interviews explain this impact pathway; participants directly experienced the advantages of digital health technology during medical visits, such as saving time, simplifying process steps, and obtaining consultation opinions or test reports more efficiently and quickly. Consequently, they prioritize the use of digital health technologies in the next medical visit, such as online appointment registration and accessing these applications and functionalities online.

Thirdly, technology anxiety has a negative impact on behavioral intention, as also confirmed by a research conducted in Bangladesh (Hoque & Sorwar, 2017). The reasons for this may stem from the lack of confidence among the elderly population in their ability to independently operate digital health-related devices, leading to anxiety hindering the acceptance and use of digital health technologies among the elderly (Nymberg et al., 2019).

Additionally, some elderly patients harbor skepticism toward new technologies, especially when these technologies are related to the medical and health field, intensifying their negative emotions (Lundell et al., 2020). The viewpoints mentioned by participants in focus group interviews complementarily explain this phenomenon. The rapid development and rapid iteration of information technology pose significant challenges for older people to grasp and adapt to these technologies. In this study, the survey subjects were all elderly individuals aged 60 and above.

Our results show that digital health functionalities carried by information and communication technology may trigger anxiety among this population – not very well prepared to use it. The sources of these emotions may be distrust and unease towards digital health technologies among the elderly or discomfort with new technologies. These perspectives can be derived from the focus group interviews in our second study. Various reasons causing negative perceptions and adverse emotions towards digital health technologies among elderly patients with chronic diseases could potentially act as significant barriers to the acceptance and use of this technology.

The variable "effort expectancy" has evolved from the variable "perceived ease of use" in the Technology Acceptance Model, while "performance expectancy" originates from the variable "perceived usefulness" in the same model (Venkatesh et al., 2003).

In the model we propose, effort expectancy exhibits a positive relationship with the performance expectancy of elderly patients with chronic diseases in using digital health technology; effort expectancy shows an inverse relationship with the technology anxiety related to digital health technology in elderly chronic disease patients.

Similar findings have been reported in previous studies. When Chinese elderly individuals adopt remote health management services, perceived usefulness depends on perceived ease of use. In other words, making digital health technology feel simpler and easier for elderly patients contributes to their willingness to use it, thus enhancing their perception of the benefits of digital health technology (W. Li et al., 2023).

The documental study (the first study) and literature review presented earlier indicates that user experience is a facilitating factor in the acceptance and utilization of digital health technology. The viewpoints expressed by participants in focus group interviews (in the second study) further validate this perspective. Despite considering smart wearable devices useful, participants pointed out issues related to their complexity, which is detrimental to patient acceptance. Instead, it makes the elderly feel cumbersome while using these technologies, thereby becoming an obstacle to the acceptance and utilization of digital health technology. Therefore, this provides crucial insight to technology developers: digital health technology products targeted at the elderly should prioritize actual needs, simplify functionalities, and ensure user convenience rather than emphasizing excessive features.

Social influence significantly and positively impacts the performance expectancy of elderly patients with chronic diseases regarding digital health technology. Previous studies have also identified interpersonal support as a promoting factor in the acceptance and usage of digital health technology. A similar study in Japan confirmed this impact pathway (Cao et al., 2022). Results from focus group discussions offer vivid explanations and insights. During hospitalization, participants sometimes acquire new knowledge and experiences related to digital health by conversing with fellow patients who possess high digital health literacy. Participants mentioned that introductions and demonstrations by fellow patients were more effective in conveying the benefits of technology applications than conventional promotional efforts. In the third study, the "social influence" variable in the presented questionnaire involved four factors: family and relatives, teachers and colleagues, friends or fellow patients, and medical staff. Data analysis from the theoretical model demonstrates that these groups play positive roles in the acceptance and usage of digital health technology by elderly patients with chronic diseases.

As revealed in earlier studies, the digital health application scenarios for elderly patients with chronic diseases involve family, community, and hospitals. Digital health literacy, assistance from friends and family, and self-empowerment are all aspects that concern elderly patients when applying digital health technology.

Thus, we advocate for increased attention to "key populations" related to elderly patients with chronic diseases. Hospitals, communities, and homes serve as optimal "classrooms" for conducting training on digital health knowledge and technology. Through various forms of frequent knowledge dissemination and experience exchange, more elderly patients with chronic diseases can learn and accept digital health technology implicitly. Simultaneously, these key populations provide more support and encouragement to the elderly, creating a favorable atmosphere for the promotion of digital health technology in the social environment.

In previous studies, there has been limited focus on the influence of facilitating conditions on effort expectancy in the field of medical health. Our research discovered a significant positive impact of facilitating conditions on effort expectancy when elderly patients with chronic diseases accept and use digital health technology, with the highest path coefficient ($\beta=0.873$, $p<0.001$). This result has been corroborated by recent research findings (Cao et al., 2022). The elderly population generally lacks confidence in their knowledge of the digital health domain, believing that these technological applications surpass their cognitive and skill capabilities (Nymberg et al., 2019).

Focus group interviews' findings show that many elderly individuals lack an understanding of digital health technology and its applications, indicating a deficiency in basic knowledge. Therefore, another factor to be considered is providing the elderly with more knowledge and resources needed to use digital health technology, enhancing their effort expectancy, and stimulating their behavioral intention to accept and use digital health technology. In the focus group discussions, interviewed elderly patients with chronic diseases also expressed the need for digital health technology usage training tailored to this population. This finding has a practical significance, and by promoting functionality and providing operational guidance, increasing the knowledge and skill reserves of the elderly regarding digital health technology can aid in raising their acceptance and usage rates of new technology.

In contrast with previous findings, we did not identify any impact of social influence on technological anxiety. Cao et al. (2022) discovered that social influence could alleviate anxiety regarding mobile healthcare among Japanese youth. However, we did not observe a similar effect of social influence on our participants.

The research location, Shanghai, is a city in China characterized by economic prosperity and high digital health literacy. In our focus group interviews, we observed that elderly patients with the capability to use digital health technology seek assistance from their children or those around them when needed. This practice may contribute to reducing negative psychological impacts. As previously discussed, benefiting from the positive impact of social influence on performance expectancy, social influence in elderly patients with chronic diseases contributes more to enhancing confidence and gaining successful experiences in using technology.

The role of social influence in the elderly chronic disease population is predominantly positive, fostering confidence and successful experiences rather than generating negative emotions. This further underscores that the geographical region and social environment in which our research took place are conducive to the acceptance and utilization of digital health technology by this population. The relationship between social influence and technological anxiety may be further explored in future research.

7.2 External and internal factors

It was pointed out that the implementation of individual health behaviors and the utilization of health services are influenced by multiple factors. The external environment affects internal attitudes and needs, thus influencing health behaviors (Andersen, 1995). Based on this concept, we proposed – in the third study – a theoretical model, KAP-UTAUT, which integrates the variables from the classic UTAUT and the latest research focus on technological anxiety.

According to the KAP theory, hypotheses about the relationships between variables are proposed and validated through questionnaire surveys and statistical analyses. The variables in this integrated model establish new logical relationships based on the three stages of knowledge-attitude-practice. The knowledge segment is mainly composed of external factors related to individual acquisition of new knowledge, including the variables "social influence" and "facilitating conditions". The attitude segment primarily consists of internal factors influencing the individual's transformation of intent into behavior, including behavioral intention, performance expectancy, effort expectancy, and technological anxiety. Almathami et al. (2020) also mentioned external and internal factors influencing digital technology. External factors include the usage environment and the system itself, affecting user acceptance and utilization of digital health technology.

Internal factors cover user behavior and motivation when interacting with the system, as well as patients' attitudes toward the advantages and disadvantages of digital health compared to traditional healthcare (Almathami et al., 2020). Based on these fundaments, we examine UTAUT-related variables in terms of internal and external factors influencing digital health technology, facilitating a more detailed understanding of the target effects of these influencing factors and better establishment of strategies for the adoption of digital health technology.

The integrated model we propose defines the knowledge stage as an external factor consisting of the variables "social influence" and "facilitating conditions," each affecting the internal factors of performance expectancy and effort expectancy. From the results, these two external factors serve as prerequisite elements for elderly individuals with chronic diseases to understand digital health technology. This includes acquiring the knowledge needed for digital health technology and the relevant conditions for technical use. These prerequisites become critical factors influencing internal factors, where external knowledge and technical usage conditions impact individuals' perceptions and cognitions of digital health technology.

The focus group discussions (in study 2) well illustrate the interaction of these variables. Patients, through obtaining new knowledge and experiences of digital health technology from fellow patients during hospitalization, are more likely to generate expectations of the benefits of digital health technology. Some patients, with the help of others, gain positive experiences in using digital health technology, which helps enhance their performance expectancy and effort expectancy. Simultaneously, during interviews, many patients expressed the need for training in digital health technology, gaining new knowledge and skills through professional training, which further helps improve patient effort expectancy.

In the attitude stage of the integrated model, which includes effort expectancy, performance expectancy, technological anxiety, and behavioral intention, these four variables collectively constitute internal factors influencing the acceptance of digital health technology. The first three variables impact behavioral intention. Among them, effort expectancy is a crucial variable, which also influences the variables of performance expectancy and technological anxiety. In this study, the factor causing technological anxiety in elderly patients with chronic diseases is the effort expectancy variable, and they are negatively correlated.

For patients who find digital health technology easy to use, the likelihood of experiencing technological anxiety is low. Participants with severe technological anxiety exhibit a weak behavioral intention to accept digital health technology. Therefore, enhancing effort expectancy is key to reducing technological anxiety, aiding elderly patients with chronic diseases in accepting digital health technology, generating behavioral intention, and promoting its use. Simultaneously, effort expectancy also contributes to improving performance expectancy, which has positive implications for enhancing the behavioral intention of elderly patients with chronic diseases to accept digital health technology. Further findings from the focus group discussions (in study 2) reveal that a decline in physiological function may lead to increased technological anxiety in elderly patients by reducing their effort expectancy. An age-friendly design of digital health products may help enhance effort expectancy and increase performance expectancy.

Behavioral intention serves as the connecting variable between attitude and practice. Performance expectancy and effort expectancy positively influence it, while technological anxiety exerts a negative impact on behavioral intention. We found (in study 3) that the behavioral intention of elderly patients with chronic diseases to use digital health technology has a significant positive effect on their actual usage behavior – result aligned with findings from numerous recent studies (Gu et al., 2021; W. Li et al., 2023; Palas et al., 2022).

We also observed that the intention to use digital health technology, when influencing the actual user behavior of elderly patients with chronic diseases, is further influenced by users' different ages, genders, and usage experiences. Older patients, those lacking usage experience, and female patients exhibit relatively lower rates of behavioral conversion. This suggests that in the process of promoting digital health technology, attention should be given to these groups. Specialized training strategies should be considered to assist them in better transforming the intention to use digital health technology into actual usage behavior.

7.3 Research summary

The three studies in our study are interconnected, interrelated and complementary, specifically: the study1 (literature study), using descriptive research and tertiary coding, allowed us to understand the current status of the use of digital health technologies in elderly patients with chronic illnesses based on a global perspective, and further revealed that there are very few studies of this kind in developing countries, especially in China, and that many of these studies come from Europe and the United States, which makes the need to carry out our study even more urgent. This makes it even more urgent and necessary to carry out our study. The study 2 (qualitative study of the focus group discussion) remedied the gaps in the literature by identifying the needs, facilitators, and barriers to the use of digital health technologies among the Chinese elderly population with chronic illnesses, which were similar to and different from the findings of the scientific literature, which further made it clear to us that there is a need to carry out this study in developing countries, and that the findings will provide a good basis for the development of digital health technologies in developing countries and regions. Some ideas for policy optimisation for digital health technology applications in developing countries and regions. Of course, since the study 2 is a single-centre small-sample qualitative study, we certainly need to carry out theoretical modelling studies to obtain more and more scientific evidence to understand more factors affecting the acceptance and use of digital health technologies. In the third study, combining the KAP theory and other scientific literature, reconstructing the core variables of the UTAUT model and expanding the new variable, technology anxiety, and setting the moderating variable at the point of action where the intention to use digital health technology is transformed into the behaviour of using it, we made an evidence-informed basis of the traditional UTAUT model Based on the main items of the UTAUT questionnaire in the scientific literature, we also used the results of the study 2 as an important reference for the setting and formulation of the questionnaire stem, and collected more samples in several general hospitals and communities, and discussed the internal and external factors affecting the acceptance and use of digital health technologies and their interrelationships through inference and validation. relationships. These three interrelated studies provide a step-by-step understanding of the perceptions, needs, and influencing factors related to the acceptance and use of digital health technologies among older patients with chronic diseases in Shanghai, China.

In order to summarize the discussion of our research, before reaching a conclusion, we further outline the research plan and present the main research results. These research findings can be summarized in these aspects: we have found that among the digital health technologies used, what are the commonly mentioned chronic diseases in the elderly? This means that elderly people with these diseases may have more exposure to digital health technologies, or the application of digital health technologies in these disease fields is more common. We have also discovered the application scenarios and usage characteristics involved in the use of digital health technology among these populations. We have identified the main driving factors and obstacles for elderly patients with chronic diseases to use digital health technology. These factors include their past experience in using digital health technology and related applications, as well as individual internal factors and external environmental factors. These factors are gradually discovered and repeated in literature research and focus group discussions, and are constantly focused and strengthened. The discussions and exchanges in the real world have also given us a deeper understanding of the digital health scenarios familiar to elderly chronic disease patients. At the same time, we have also clarified some viewpoints, namely, the value of these digital health technologies in their acceptance of health services for elderly chronic disease patients, the needs of these groups for digital health technologies, the challenges they face, and the possible directions for optimizing digital health technologies. Especially, with the introduction of theoretical models, we have gained a clearer understanding of the impact of various variables on the acceptance and use of digital health technologies by elderly chronic patients, as well as the interaction characteristics between the variables. By verifying the role of these variables in the model, we have gained a theoretical understanding of how digital health technology plays a role in the dissemination process for elderly individuals with chronic diseases. Understanding this result has also laid an evidence-based foundation for optimizing and improving strategies for promoting digital health technology and application scenarios in the elderly population with chronic diseases. The research conclusion framework based on the overall design of this study is shown in Figure 7.1.

Title

Digital support or digital divide: Strategies to improve digital health applications and services for elderly patients with chronic diseases, in Shanghai

Literature review

Global aging and chronic diseases	Digital health applications and elderly chronic diseases	Digital health application policies in China	Technology acceptance models (including in public health research)	Digital health applications and services for elderly patients

Population (Main Participants: elderly chronic disease patients, in Shanghai)

Research questions

What are the perceptions and needs of elderly chronic disease patients about digital health technologies (in different scenarios)?	What are the influencing factors that affect the adoption of digital health applications by elderly chronic disease patients?

Main Objectives

1. Verify how the service strategies and digital health technologies have been approached in scientific research.	**2.** Identify the types of digital health application scenarios and the use of digital health technology	**3.** Identify the needs of elderly chronic disease patients for digital health technology and application scenarios.	**4.** Propose and validate a conceptual model to explain the acceptance and use of digital health technologies by elderly chronic disease patients.	**5.** Identify the factors that affect the accepta nce and use of digital health technol ogies.	**6.** Propose suggestions to facilitate the adoption of digital health technologies by elderly chronic disease patients.

Studies

1. Documental – Qualitative Bibliographical study – Select scientific papers that enrich the literature review (with a meta-analysis), giving findings, through descriptive analysis and qualitative research, that contribute to determine the pain points in the present scien-tific field, and redefine the subsequent studies.	**2.** Focus group – Qualitative Focus group discussions – The interview outline is based on the topics or concepts obtained from the previous study and the literature review, using nVivo for textual data analysis and the grounded theory to interpret the results.	**3.** Inferential – Quantitative Qustionnaire Survey- A questionnaire was developed to evaluate the variables (and their causal relations) in a proposed conceptual model to explain the adoption of digital health technologies by elderly chronic disease patients. The data are analyzed by statistical techniques, through SPSS and smartpls – using SEM (Structured Equation Model).

Main Results

1) COPD and diabetes were the most frequently discussed diseases. The application of digital health in elderly chronic diseases includes medical services, health management, disease management, and social management. In the early studies we reviewed, the most attention was paid to physiological data monitoring tools and internet health consulting services, the most common chronic disease population that uses digital health technology is COPD patients.
2) According to the qualitative analysis of the literature, the main drivers of elderly chronic disease patients using digital health are user experience and interpersonal support, while the main barriers are ability awareness, technical factors, and security.
3) Based on the focus group discussion, the digital health application scenarios encountered and used by elderly patients with chronic diseases mainly involved online appointment, online enquiry, online consultation, and remote monitoring.
4) Digital health applications have the advantages of reducing the time of medical treatment, quickly learning about the condition, and simplifying the process of medical treatment. The mistrust of digital health technology, physiological downgrading, infrequent use of digital health apps, and burnout in learning new knowledge, coupled with the need to improve the aging-appropriate design of digital health products, the subjective willingness of older patients with chronic diseases hinders actual use behaviour.
5) Older patients with chronic diseases expressed some needs for digital health technology and applications, including the hope for more promotion and publicity, more reliable training, more functionality in a simplified design, and the need for help from others in the process of using it.
6) Technology anxiety had a significant negative impact on behavioural intention; effort expectancy and performance expectancy had a significant positive impact on behavioural intention; effort expectancy had a negative impact on technology anxiety; facilitating conditions had a significant positive impact on effort expectancy; social influence and effort expectancy had a significant positive impact on performance expectancy; and behavioural intention had a significant positive influence on use behaviour.

Figure 7.1 Summarized research planning with results

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Chapter 8: Conclusions

8.1 Main conclusions

The present research reveals that digital health technology is rapidly and extensively applied worldwide, including in Shanghai, China. The elderly population suffering from chronic diseases constitutes a significant user group for digital health technology. Both literature reviews and real-world observations emphasize the importance of investigating the scenarios, demands, obstacles and facilitating factors associated with the utilization of this technology.

Our research conducted in Shanghai, China, exploring the real-world application of digital health technology among elderly patients with chronic diseases, effectively address and explore two main (research) questions: 1) What are the perceptions and needs of elderly chronic disease patients about digital health technologies (in different scenarios)?; 2) What are the influencing factors (facilitators and barriers) that affect the adoption of digital health applications by elderly chronic disease patients? To address these research questions, we conducted three studies, including a documental study, a qualitative study in form of focus group discussions and a quantitative study with a questionnaire survey.

It concludes that while digital health technology brings numerous benefits to elderly patients with chronic diseases, its in-depth application presents a combination of opportunities and challenges. According to our documental study, several factors may affect the use of digital health technologies of the older patients with chronic diseases, including user experience, interpersonal support, the support from others, self-efficacy, psychological aversion and resistance, technical malfunctions and so on. Through the focus group discussion, Digital health applications have the advantages of reducing the time of medical treatment, quickly learning about the condition, and simplifying the process of medical treatment. The mistrust of digital health technology, physiological downgrading, infrequent use of digital health apps, and burnout in learning new knowledge, coupled with the need to improve the aging-appropriate design of digital health products, the subjective willingness of older patients with chronic diseases hinders actual use behaviour.

Grounded in the Knowledge-Attitude-Practice (KAP) theory and the extended Unified Theory of Acceptance and Use of Technology (UTAUT), and to propose a new conceptual model, the third study introduced the KAP-UTAUT integrated model to explain the adoption of digital health technology by elderly patients with chronic diseases. We confirmed that technological anxiety, effort expectancy, and performance expectancy are crucial influencing factors for the acceptance and usage of digital health technology among elderly patients in China. Additionally, facilitating conditions affect effort expectancy, and this influences technological anxiety and performance expectancy – which in turn is affected by social influence. We have found that the adoption of digital health technology by elderly patients is influenced by a combination of personal internal factors and external environmental factors, with personal internal factors playing a more significant role. External factors contribute positively to the formation of favourable internal factors in individuals.

Our research provides theoretical guidance for a better utilization of digital health technology by the elderly population. Furthermore, it offers essential reference points for the optimization of digital health technology, policy-making, and improvement of the social environment.

8.2 Contributions of the research

8.2.1 Theoretical contributions

Based upon the extension of the UTAUT model, we integrated the Knowledge-Attitude-Practice (KAP) theory and proposed the KAP-UTAUT conceptual model. It conducts a detailed examination of the process of formation and the roles of various influencing factors in the acceptance and adoption of digital health technology – allowing significant theoretical contributions to a better understanding of the mechanisms behind the formation of behaviour regarding digital health technology.

Previous research efforts often confined themselves to discovering and adding new variables within the existing model framework, resulting in different extended models. These prior studies revolved around these newly added variables to investigate their impact on behavioural intention or use behaviour. In contrast, in the present research we adopted a different approach – the third study combines the foundation of the Knowledge-Attitude-Practice theory and reconstructs the UTAUT extended model. Following the theoretical idea that knowledge propels the formation of attitudinal attitudes, and attitudinal attitudes drive behavioural transformation, the study proposes new assumptions and validations regarding the relationships between various variables in the UTAUT extended model. Utilizing real-world digital data, including favourable factors, obstacles, scenarios, and needs, the study explains the mutual influences of the model's various variables and discusses their mechanisms of action.

This research significantly enriches the theoretical content while developing the acceptance and adoption model of digital health technology, giving a valuable contribution to the theory domain.

To the best of our knowledge, there are few studies that simultaneously reconstruct the acceptance and adoption model of digital health technology and focus on the adoption behaviour of the elderly population from both individual and environmental perspectives. We employed a mixed-methods approach, combining qualitative and quantitative research, to confirm the multiple influences of internal and external factors on the acceptance and use of digital health technology. A crucial insight derived from this methodological approach is that when addressing the adoption of digital health technology, attention was not only given to the role of individual variables but also considered the combined effects of personal internal factors and external environmental factors. Furthermore, we found that these variables operate within mutual influence and dynamic change. Taking the impact of social influence on technological anxiety as an example, we did not find the former affecting the latter – suggesting that different regions and different subjects, such as age, digital literacy, or other potential factors, may influence the outcome. To study the adoption of digital health technology, it is inadequate to simply observe the impact of individual variables on behavioural intention or use behaviour in a simplistic and isolated manner. Attention should be directed towards the collaborative effects, chain reactions, and mutual influences between variables.

8.2.2 Practical contributions

In the future, digital health technology will play a more critical role in the management of chronic diseases among the elderly, providing widespread medical benefits to elderly patients with chronic diseases. Therefore, through model construction and empirical research, it is of paramount importance to scientifically explore the influencing factors of the intention of elderly patients with chronic diseases to use digital health services.

This exploration is crucial for enhancing the acceptance and usage of digital health technology among elderly patients, cultivating habits of sustained use, and maximizing the value of digital health services. The classical Social Ecological Model (SEM) was introduced into the field of medical health, indicating that individual health behaviour is influenced by five different levels of factors: individual, interpersonal, organizational, and policy factors

(McLeroy et al., 1988). Based on the evidence obtained in this study in terms of patients' needs, perspectives and influencing factors, we propose the following strategies to optimise the acceptance and use of digital health technologies among older patients with chronic diseases, based on the theoretical framework of social ecology.

Strategy 1 (the individual level): our research findings indicate that the elderly population with chronic diseases, facing the dual challenges of aging physiology and diseases, has specific needs for digital health technology. Therefore, the development of digital health technology and related products should align with the concept of aging in place. Additionally, gender, age, and usage experience significantly influence the intention of elderly patients with chronic diseases to go from the intention to use digital health technology to an actual usage behaviour. Hence, when promoting digital health technology, attention should be paid to the characteristics of different groups, especially developing specific strategies for female, elderly, and inexperienced users to facilitate the transformation from behavioural intention to practice.

Strategy 2 (the interpersonal level): social influence significantly affects the performance expectancy of elderly patients with chronic diseases regarding digital health. Support from peers and children is a crucial factor influencing elderly patients' use of digital health technology. Therefore, leveraging positive peer support among elderly patients can involve those with experience in using digital health technology sharing their experiences and successes, demonstrating operations in various scenarios, enhancing the emotional understanding of the advantages of digital health technology among the elderly, mitigating distrust, and promoting their acceptance and adoption. Furthermore, children and relatives should actively inquire about the elderly's awareness and use of digital health technology, encourage them, and promptly provide assistance to enhance their confidence in learning and using it.

Strategy 3 (the organizational level): this study shows that performance expectancy, effort expectancy, and technological anxiety significantly influence behavioural intention. This insight is crucial for the development and use of digital health technology. Providers of digital health services should thoroughly understand the problems and needs of the elderly user group during the usage process. Similarly, medical institutions, as the primary platforms for digital health, should do the same. By increasing font size, setting conspicuous icons, providing straightforward prompts, and configuring usage assistants or volunteers, the interaction difficulty between the elderly patient group and these technological devices and software during the use of digital health technology can be reduced. This makes the interface and functionality more aligned with the usage characteristics of the elderly group, streamlining and optimizing the performance of digital health products and services. Additionally, the significant impact of effort expectancy on performance expectancy and technological anxiety requires further optimization of the design of digital health applications. Only by making the elderly feel that digital health technology is easy to use can they be more willing to use it.

Strategy 4 (the community level): based on the finding that facilitating conditions significantly affect effort expectancy, enriching the knowledge base of the elderly patients with chronic diseases may alleviate their difficulty in using digital health technology. The community plays a crucial role in this context. Community healthcare institutions are organizations that elderly patients contact more frequently and trust more than other kinds of medical institutions, and these organizations should provide better conditions or opportunities for the elderly with chronic diseases to learn and use digital health technology. Community volunteers can conduct digital health technology training for elderly patients, supplemented with the distribution of learning manuals or videos, assisting this group in enhancing digital health literacy and improving their ability to use technology practically.

Strategy 5 (the policy level): it primarily involves the responsibilities that the government should undertake as digital health technology rapidly spreads. Another practical application area where facilitating conditions affect effort expectancy is the greater role that the government should play in social propaganda and promoting the application of digital technology. Television or mobile phones are the most used tools for elderly patients with chronic diseases. Systematically developing digital health technology videos, like strategies for disease prevention, to carry out the propaganda and mobilization of digital health technology is essential. The format can be diverse, choosing ways that the elderly find more acceptable, letting elderly patients understand the knowledge of this technology, increasing expectations for this technology, eliminating concerns during usage, learning, and improving the ability to use technology, thereby creating favourable conditions for the elderly to better use these technologies in society.

8.3 Limitations and suggestions for future research

8.3.1 Limitations

Our research has revealed important findings, but there are still some limitations. Firstly, we conducted on-site surveys by distributing questionnaires in Shanghai. Being Shanghai a mega city with certain unique characteristics, concerns may arise regarding the generalization of the results. In addition, we mainly focused on the five major chronic diseases with higher prevalence rates in the elderly population: hypertension, diabetes, coronary heart disease, stroke, and chronic obstructive pulmonary disease, without including cancer patients. Lastly, we only considered elderly patients with the ability for self-care.

8.3.2 Suggestions for future research

Future research should further expand the scope of the present investigation, including samples from different populations and geographical factors, providing more valuable evidences for the popularization and development of digital health technology and various applications in the elderly population.

The influence of digital health knowledge on the digital health behavioural intentions of Chinese elderly chronic disease patients was not found in this study, which differs from the findings in younger age groups in developed countries. In future research, it is necessary to conduct controlled studies in different age groups to further clarify the impact of digital health literacy on different age participants.

Given that many recent studies have confirmed the enormous potential of digital health technology to improve health behaviours in cancer patients (Hou et al., 2020; Jung et al., 2023), the adoption behaviour of cancer patients for digital health applications should not be ignored in future research.

With increasing age and physical function degradation, elderly patients may gradually lose the ability to behave themselves. Different health conditions of elderly individuals may affect their intentions to use mobile health technology to varying extents (J. Liu et al., 2023). Therefore, future research also needs to focus on the use of digital health technologies by older adult populations with personality traits, self-efficacy, or the presence of older patients with reduced self-care skills.

Family is an important scenario for health management of chronic diseases in the elderly, which should be paid attention to in the evaluation of digital health technology. Besides, in the UTAUT questionnaire survey, the questionnaire design and the combination with the policy culture of each country, optimising the presentation of UTAUT questionnaire items and better understanding of different populations are also the directions of subsequent research.

Final note

Based on the proposed KAP-UTAUT model, our findings provide valuable theoretical guidance for the elderly chronic disease patients to promote their adoption of digital health technology and presents empirical scientific evidence for the priorities of digital health technology design, policy making, and social environment.

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Annex A: Technology Acceptance Models

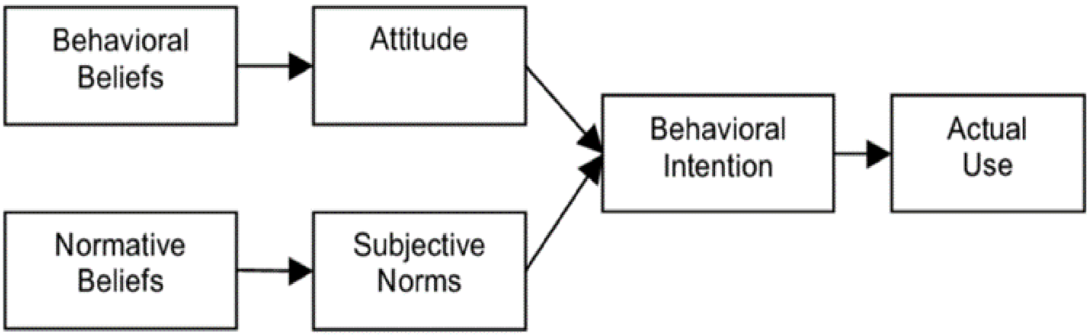


Figure A.1 Theory of Reasoned Action

Source: Fishbein and Ajzen (1977)

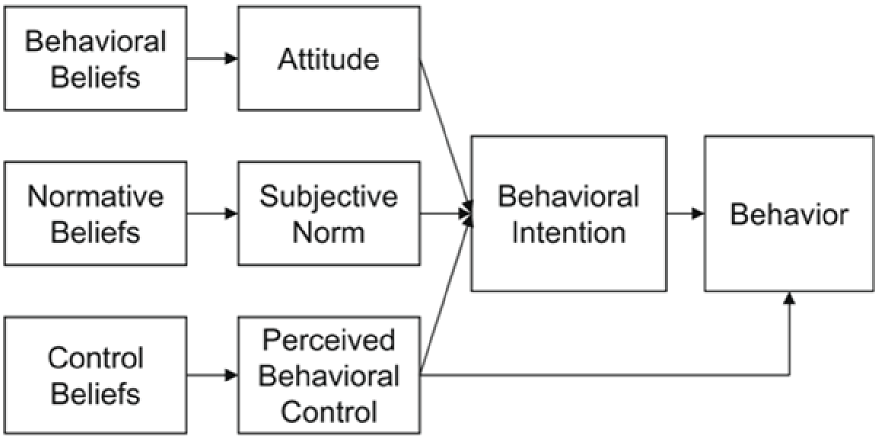


Figure A.2 Theory of Planned Behavior

Source: Ajzen (1991)

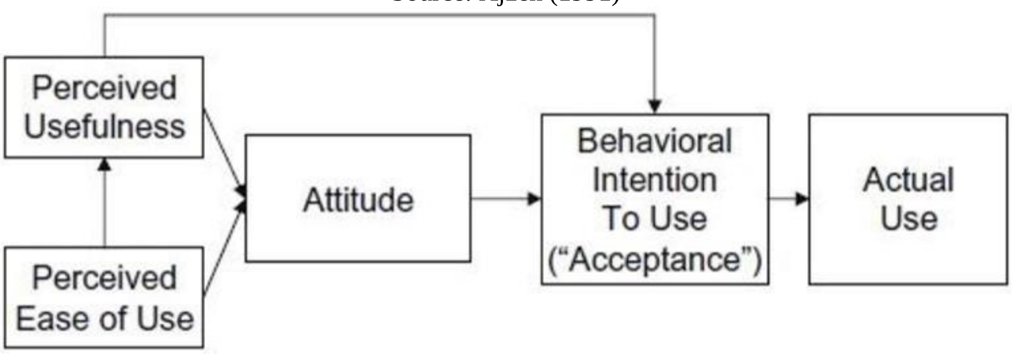


Figure A.3 Technology Acceptance Model

Source: Davis (1989)

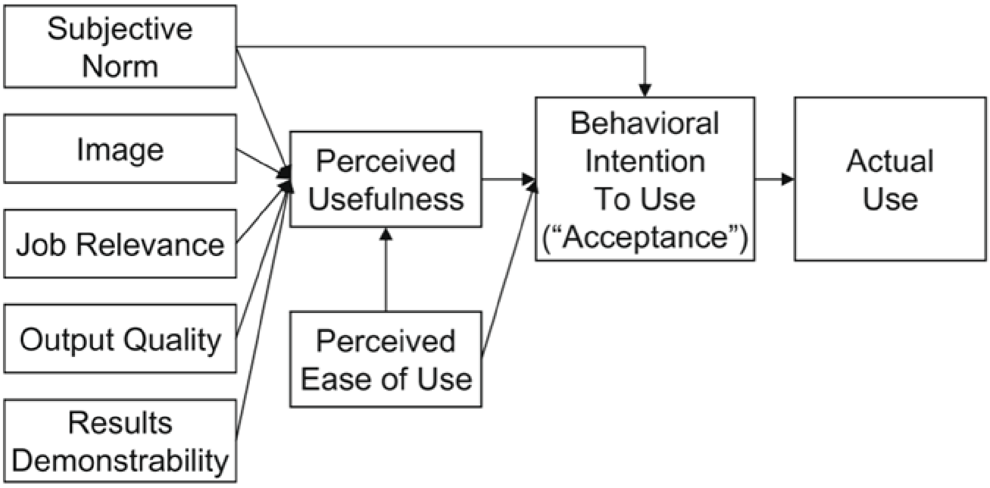


Figure A.4 Technology Acceptance Model 2 (TAM2)

Source: Venkatesh and Davis (2000)

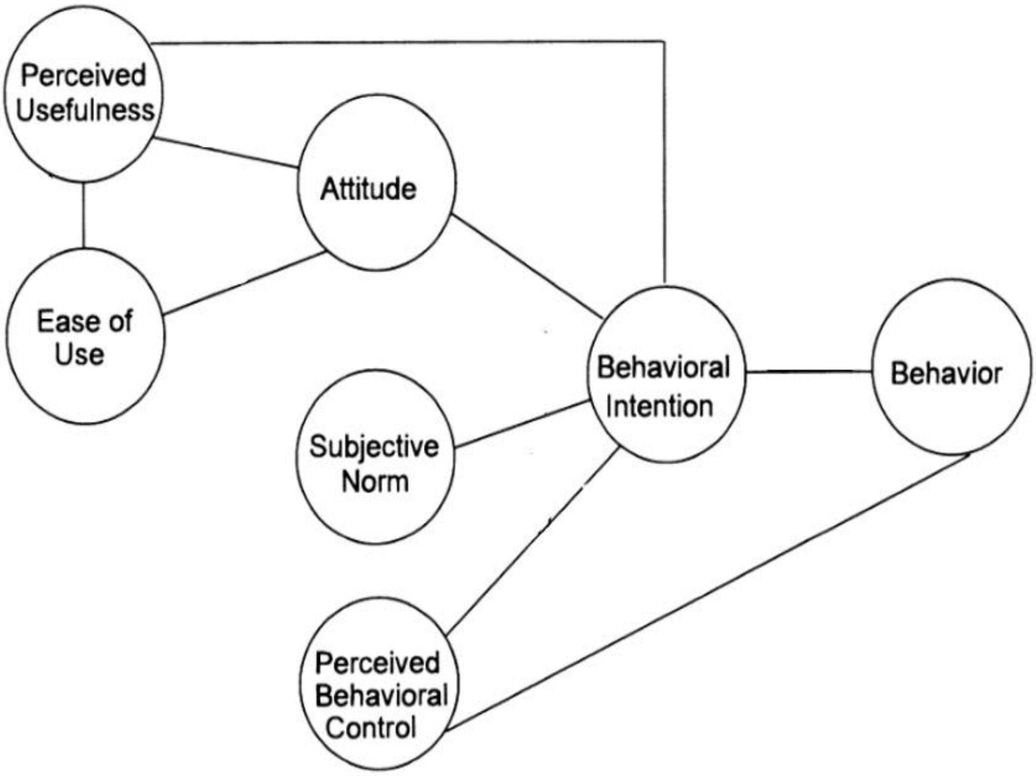


Figure A.5 Combined TAM and TPB (C-TAM-TPB)

Source: Talyor and Todd (1995)

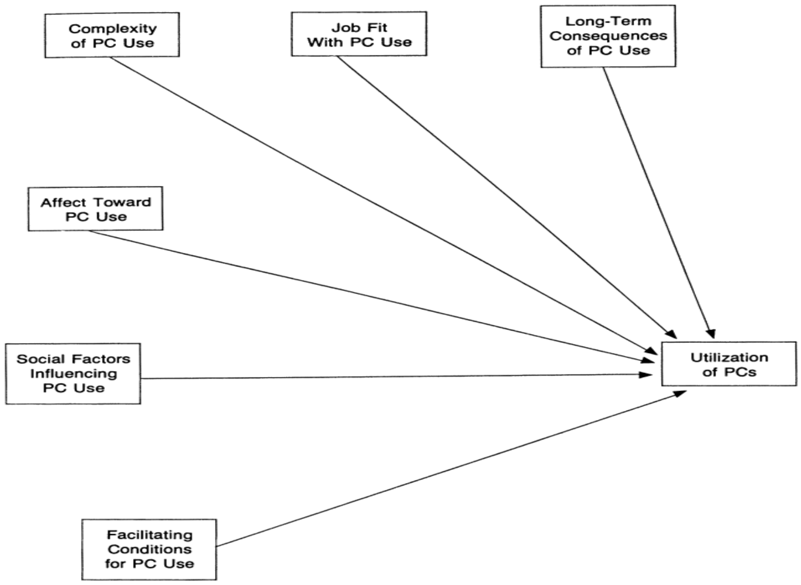


Figure A.6 Model of PC Utilization (MPCU)

Source: Thompson et al. (1991)

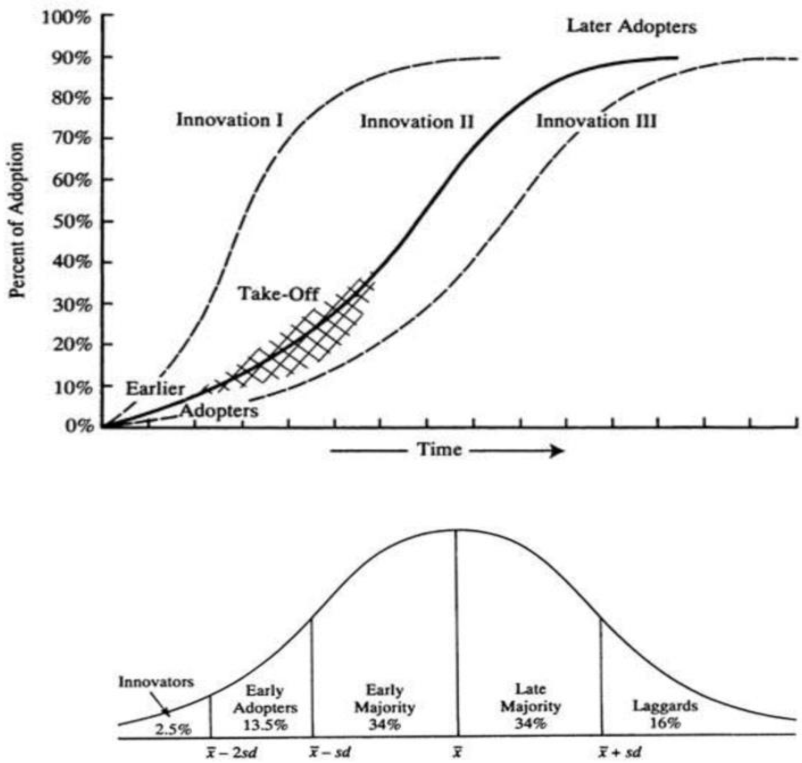


Figure A.7 S-shaped curve of Innovation Diffusion Theory (IDT)

Source: Rogers (2003)

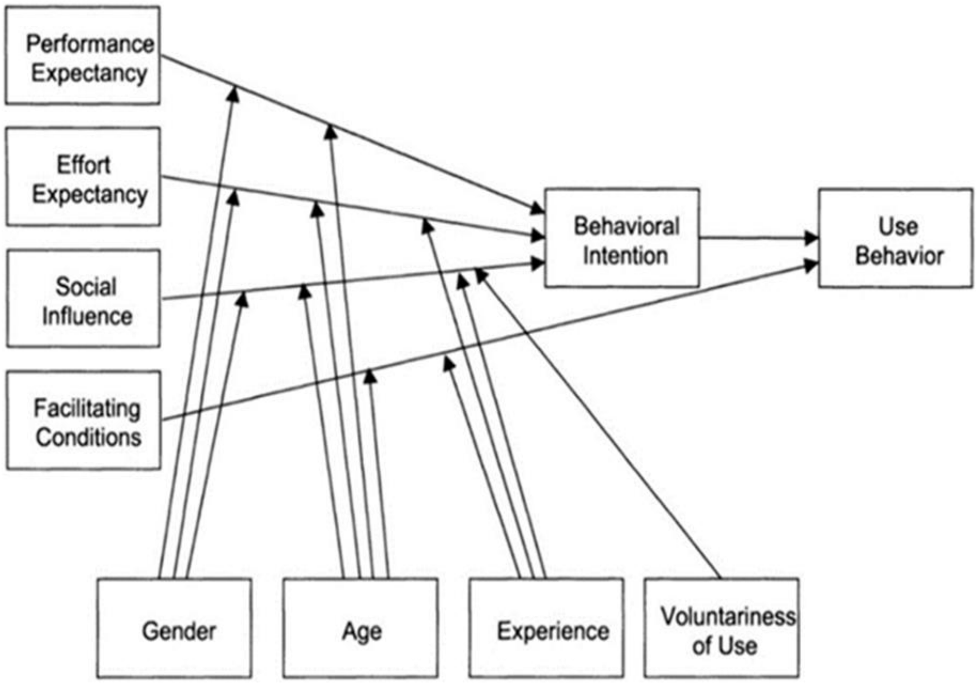
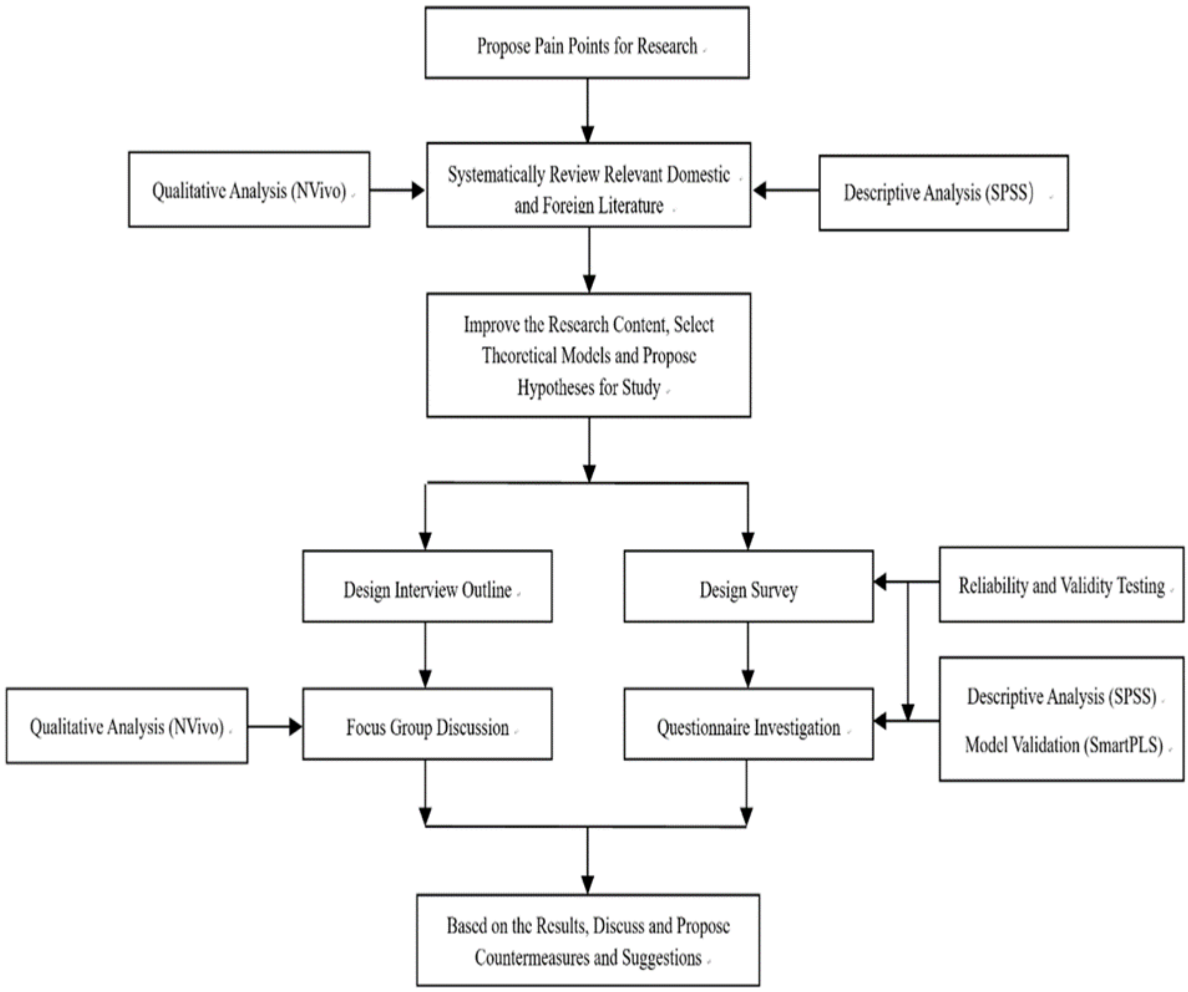


Figure A.8 Unified Theory of Acceptance and Use of Technology (UTAUT)

Source: Venkatesh et al. (2003)

Annex B: Research Design Process Diagram



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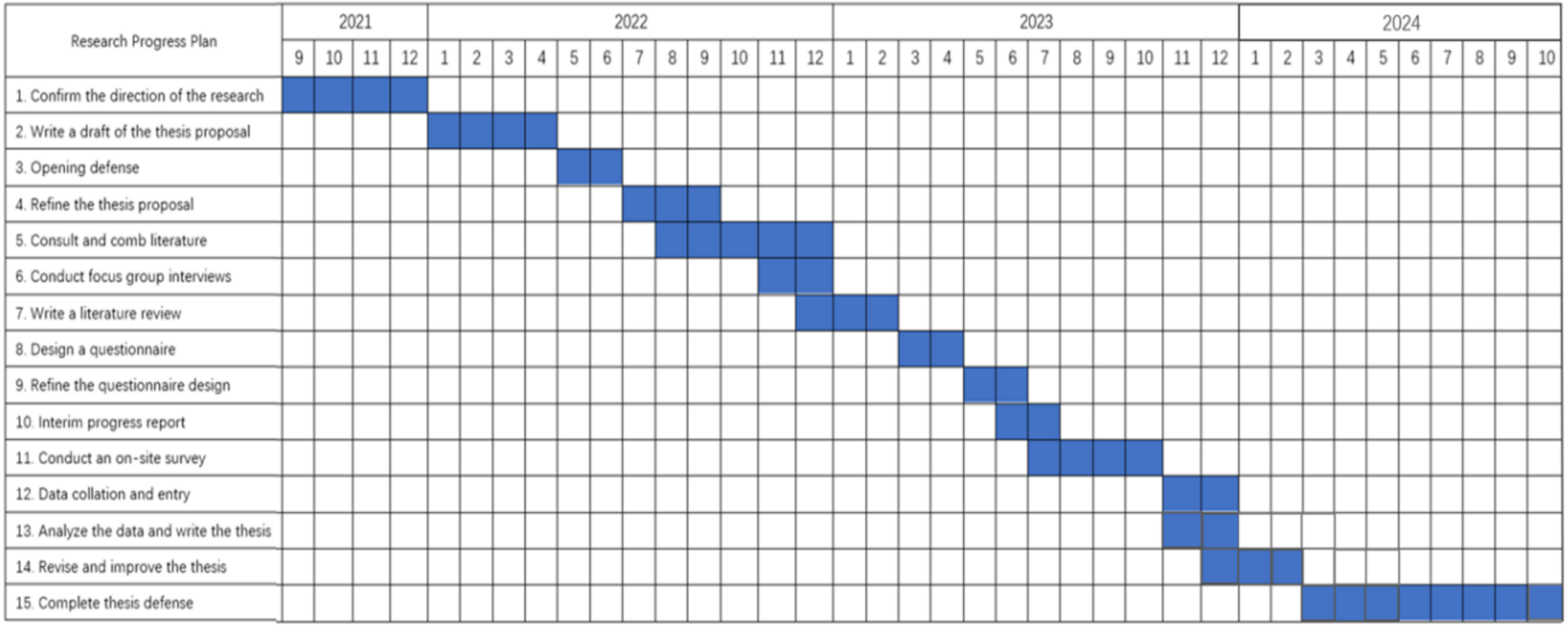
Annex C: Research Progress Plan



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Annex D: Ethics Approval

Approval Letter Ethics Committee of Xinhua Hospital Affiliated to Shanghai Jiaotong University School of Medicine

Approval number: XHEC-C-2022-110-1 **Meeting No./Date: NA**

Protocol Title/Number	Strategic research on the application of digital health services among the elderly population
Reviewed documents	1. Clinical research ethics review application: 2. Clinical research protocol 1.1/202210.27); 3. Interview informed consent form (1.1/2022.10.27); 4. Resume of main researchers
Clinical trial approval number/clinical trial notification	NA
Study Product	NA
Phase of study	□Phase I clinical trials; □Phase II clinical trials; □Phase III bed test; □Phase IV clinical trials; □Medical device registration trials; □Post market research on medical devices; □Diagnostic reagent registration test; □Post market clinical research; ■Clinical studies initiated by researchers; □Other ____________________
Type of review	□Meeting review;■Rapid review (preliminary review); □Emergency meeting review
Study site /PI	Shanghai Jiao Tong University School of Medicine Affiliated Xinhua Hospital, Zhao Libin
Sponsor	Shanghai Jiao Tong University School of Medicine Affiliated Xinhua Hospital

Recommendation

·**Review result:** Agreed. Please strictly follow the approved research protocol and informed consent form to conduct this study

·**Tracking review frequency:** □3 months, □6 months, ■12 months, □Not applicable

Chairman (signature):

Medical Ethics Committee of Xinhua Hospital Affiliated to Sha nghai Jiao Tong University School of Medicine

Notes:

1. Approved projects should be executed in accordance with the approved plan of this ethics committee, and should follow the guidelines of the National Medical Products Administration The National Health Commission's Quality Management Standards for Clinical Trials of Flying Drugs (2020) and Medical Device Trials (2022), as well as the National Health and Family Planning Commission's Ethical Review Measures for Biomedical Research Involving Human Health (2016), WMA's Helsinki Language (2013), CIOMS/WHO's International Code of Ethics for Research Involving Human Health (2016), and relevant laws and regulations such as ICIL-GCP.
2. This clinical trial should be carried out within one year from the date of approval by the ethics committee. If it is not carried out within the deadline, this approval will be automatically invalidated.

During the research process, any modifications made to the research protocol, informed consent form, and other related documents must be submitted to the ethics committee for review.

4. In order to eliminate emergency hazards to the subjects, if the researcher modifies or deviates from the trial protocol without the consent of the ethics committee, they should promptly report to the ethics committee and the sponsor, explain the reasons, and if necessary, report to the drug regulatory department.
5. After receiving the relevant safety information of the clinical trial provided by the sponsor, researchers should promptly sign and read it, consider the treatment of the subjects, and communicate with the subjects as soon as possible if necessary to make corresponding adjustments. They should also report any suspicious and unexpected serious adverse reactions provided by the sponsor to the ethics committee.
6. If the applicant terminates or suspends the clinical trial, the researcher shall immediately report to the clinical trial institution and ethics committee, and provide detailed written explanations.
7. If the ethics committee terminates or suspends a clinical trial that has already been approved, the researcher shall immediately report to the clinical trial institution and sponsor, and provide detailed written explanations

Researchers should submit annual reports on clinical trials to the ethics committee.

9. In case of situations that may significantly affect the implementation of clinical trials or increase the risk to participants, researchers should promptly report in writing to the sponsor, ethics committee, and clinical trial institution.
10. After the clinical trial is completed, the researcher should provide a summary of the clinical trial results to the ethics committee.

Address:No.1665 Kongjiang Road Shanghai, P.R China,Postcode:200092 Tel: +86-21-25076141 Fax: +86-21-25078922

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Annex E: Retrieval Strategy

1. Retrieval strategy for digital health applications for elderly chronic diseases

Pubmed:

((Digital health[Title/Abstract] OR eHealth[Title/Abstract] OR mHealth[Title/Abstract] OR e-Consult[Title/Abstract] OR e-Appointment[Title/Abstract] OR e-Prescription[Title/Abstract] OR e-Lab[Title/Abstract] OR e-Dossier[Title/Abstract] OR e-File [Title/Abstract] OR big data[Title/Abstract]) AND ((((((((((Chronic Disease[MeSH Terms]) OR (Chronic Diseases[Title/Abstract])) OR (Disease, Chronic[Title/Abstract])) OR (Chronic Illness[Title/Abstract])) OR (Chronic Illnesses[Title/Abstract])) OR (Illness, Chronic[Title/Abstract])) OR (Chronic Condition[Title/Abstract])) OR (Chronic Conditions[Title/Abstract])) OR (Condition, Chronic[Title/Abstract])) OR (Chronically Ill[Title/Abstract]))) AND ((((Aged[MeSH Terms]) OR (Elderly[Title/Abstract])) OR (Aged, 80 and over[MeSH Terms])) OR (Oldest Old[Title/Abstract]))

Embase:

('Digital health':ab,ti OR 'eHealth':ab,ti OR 'mHealth':ab,ti OR 'e-Consult':ab,ti OR 'e-Appointment':ab,ti OR 'e-Prescription':ab,ti OR 'e-Lab':ab,ti OR 'e-Dossier':ab,ti OR 'e-File':ab,ti OR 'big data':ab,ti) AND ('Chronic Disease':ab,ti OR 'Disease, Chronic':ab,ti OR 'Chronic Illness':ab,ti OR 'Chronic Illnesses':ab,ti OR 'Illness, Chronic':ab,ti OR 'Chronic Condition':ab,ti OR 'Chronic Conditions':ab,ti OR 'Condition, Chronic':ab,ti OR 'Chronically Ill':ab,ti) AND ('Aged':ab,ti OR 'Aged, 80 and over':ab,ti OR 'Elderly':ab,ti OR 'Oldest Old':ab,ti)

Cochrane Library:

#1 (Digital health or eHealth or mHealth or e-Consult or e-Appointment or e-Prescription or e-Lab or e-Dossier or e-File or big data):ti,ab,kw

#2 MeSH descriptor: [Chronic Disease] explode all trees

#3 (Chronically Ill or Chronic Condition or Chronic Conditions or Condition, Chronic or Illness, Chronic or Chronic Illness or Chronic Diseases or Disease, Chronic or Chronic Illnesses):ti,ab,kw

#4 #2 or #3

#5 MeSH descriptor: [Aged] in all MeSH products

#6 (Elderly):ti,ab,kw

#7 MeSH descriptor: [Aged 80 and over] explode all trees

#8 (Oldest Old):ti,ab,kw

#9 #5 or #6 or #7 or #8

#10 #1 and #4 and #9

Web of Science:

((TI=(Digital health or eHealth or mHealth or e-Consult or e-Appointment or e-Prescription or e-Lab or e-Dossier or e-File or big data)) AND TI=(Chronically Ill or Chronic Condition or Chronic Conditions or Condition, Chronic or Illness, Chronic or Chronic Illness or Chronic Diseases or Disease, Chronic or Chronic Illnesses)) AND TI=(Aged or Elderly or Oldest Old or Aged, 80 and over)

Scopus:

TITLE-ABS (("Digital health" OR "eHealth" OR "mHealth" OR "e-Consult" OR "e-Appointment" OR "e-Prescription" OR "e-Lab" OR "e-Dossier" OR "e-File" OR "big data") AND ("Chronically Ill" OR "Chronic Condition" OR "Chronic Conditions" OR "Condition, Chronic" OR "Illness, Chronic" OR "Chronic Illness" OR "Chronic Diseases" OR "Disease, Chronic" OR "Chronic Illnesses") AND ("Aged" OR "Elderly" OR "Oldest Old" OR "Aged, 80 and over"))

2. Retrieval Strategy for Technology Acceptance and Adoption Theories

Pubmed:

((KAP model[Title/Abstract] OR knowledge-attitude-practice[Title/Abstract]) OR Theory of Reasoned Action[Title/Abstract] OR Theory of Planned Behaviour [Title/Abstract] OR Technology Acceptance Model[Title/Abstract] OR Unified Theory of Acceptance and Use of Technology[Title/Abstract]) AND (Digital health[Title/Abstract] OR eHealth[Title/Abstract] OR mHealth[Title/Abstract] OR e-Consult[Title/Abstract] OR e-Appointment[Title/Abstract] OR e-Prescription[Title/Abstract] OR e-Lab[Title/Abstract] OR e-Dossier[Title/Abstract] OR e-File [Title/Abstract] OR big data[Title/Abstract])

Annex F: Focus Group Interview Field Notes Sheet Elderly Chronic Disease Patients and Digital Health Application Optimization Study

Date: Place: Duration: NO.:

Interviewer（I）	Interviewee（P）
1、Understanding ■ Do you know about digital health applications? What are available in Shanghai? ■ What are the differences between □ and traditional service delivery methods?	
2、 Demand ■ What applications are most commonly used by? What are the most common occasions to see a doctor? ■ Do you want to use these apps when you need health services? Why?	
3、Expectations, preferences and attitudes ■ Attitudes and expectations about digital health applications and related technologies? Why?	
4、Knowledge and Competencies ■ What knowledge and competencies should you have to use digital health technologies? Why?	
5、Application technology experience It may involve: identification, e-payment, online appointment, online consultation, online report, online prescription, e-paperwork, internet hospital, mobile health, health logistics, medical wearable, robotics, big data, and other smart services. ■ What applications have you heard of? Which ones have you used? How do you feel? Why?	

■ Which ones do you think are better than traditional methods, and would you like to continue using them? ■ Do you have enough knowledge and ability to use these new things? ■ Do you need help in using them? Can I get it in time?	
6、Motivation ■ What digital applications do people like? Are there any applications that you particularly want to learn? Why? ■ Are you willing to use digital applications more often? Any motivation? Where does it come from? ■ What support would be needed to encourage greater use of apps? ■ Do digital apps help people see their doctor? Why?	
7、Barriers ■ What apps do people dislike? Why? ■ Did you ever have trouble using the app? Did you get help in time? Why? ■ What other factors or concerns limit the use of the app? ■ Are there any other factors that affect the use of the app by elderly patients?	
8、Scenarios It may involve: outpatient, inpatient, acute care, home, or community. ■ In which settings are the apps typically used? What is the evaluation and experience (reception or rejection)? ■ How do apps relate to traditional services: unnecessary, complementary, or necessary? Why?	
9、Other ■ What is the overall view of digital health apps on access to health care? (useful or useless, beneficial or detrimental?) Why?	

Recorder

Annex G: Items of UTAUT questionnaire, sources and related to the study 2 (focus group)

Items		Sources	Items related to Study 2 (focus group)
Performance Expectancy	PE1. Digital health applications can be useful in managing my daily health.	Adapted from (Li et al., 2023)	
	PE2. Digital health applications can help me receive medical treatment more conveniently.		Facilitators: reduced time for medical visits, streamlined medical visit process
	PE3. Digital health applications can improve my health level and quality of life.		Facilitators: prompt awareness of health conditions
	PE4. Digital health applications are useless for my health or medical services.*	By authors	
Effort Expectancy	EE1. It’s easy for me to accept digital health applications.	Adapted from (Li et al., 2023)	
	EE2. Learning how to use digital health applications is easy for me.	Adapted from (Cao et al., 2022)	
	EE3. Using digital health applications is easy for me.		
	EE4. It's worth learning how to use digital health apps (to help me).		
Social Influence	SI1. Family members or relatives influence me to use digital health apps.	Adapted from (Cao et al., 2022)	Needs: assistance from others, reliable training
	SI2. Teachers and colleagues influence me to use digital		Needs: assistance from others, reliable

	health applications.		training
	SI3. Friends (or fellow patients) influence me to use digital health applications.		Needs: assistance from others, reliable training
	SI4. Medical staff influence me to use digital health applications.		Needs: assistance from others, reliable training
Facilitating Conditions	FC1. I have the knowledge necessary to use digital health applications.	Adapted from (Cao et al., 2022)	Needs: increase promotion, reliable training
	FC2. When I have difficulties using various digital health applications, I can get help from others.		Needs: assistance from others
	FC3. When using digital health applications, I have access to various resources to support me (software, network, equipment, hardware environmental conditions, etc.).		Needs: reliable training
	FC4. The use of digital health applications does not contradict my use of other technologies, functions, services, needs, etc.		
Technology Anxiety	TA1. Using digital health applications may make me feel uneasy and confused.	Adapted from (Patil et al., 2020)	Barriers: design issues in digital health products Needs: design simplification
	TA2. Using digital health applications would make me very nervous.		
	TA3. Using digital health applications may make me feel uncomfortable.		
	TA4. I feel calm to use digital health applications.*	By authors	Barriers: lack of trust in digital health

			technology
Behavioral Intention	BI1. I plan to use digital health applications frequently.	Adapted from (Cao et al., 2022; Li et al., 2023)	
	BI2. I'm willing to recommend digital health applications to others.		
	BI3. I don't intend to use digital health applications for the next six months.*	Adapted from (Akdur et al., 2020)	
	BI4. I intend to use (more) digital health applications as soon as possible.		
User Behaviour	UB1. I have used digital health technology and various applications.	Adapted from (Li et al., 2023; Zhou et al., 2021)	
	UB2. Using digital health applications is a pleasant experience.		
	UB3. When I need to seek healthcare service, digital health applications will be very important options for me.		
	UB4. Using digital health applications helps me to manage my self-care (for my health).		

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Annex H: Instructional Legend

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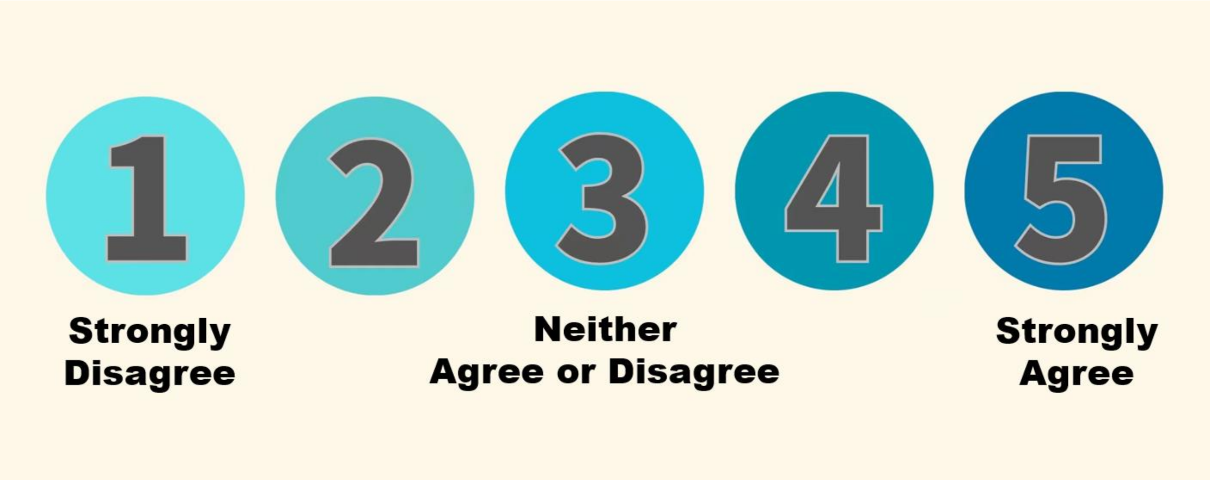
Annex I: Five-point Scale Ruler



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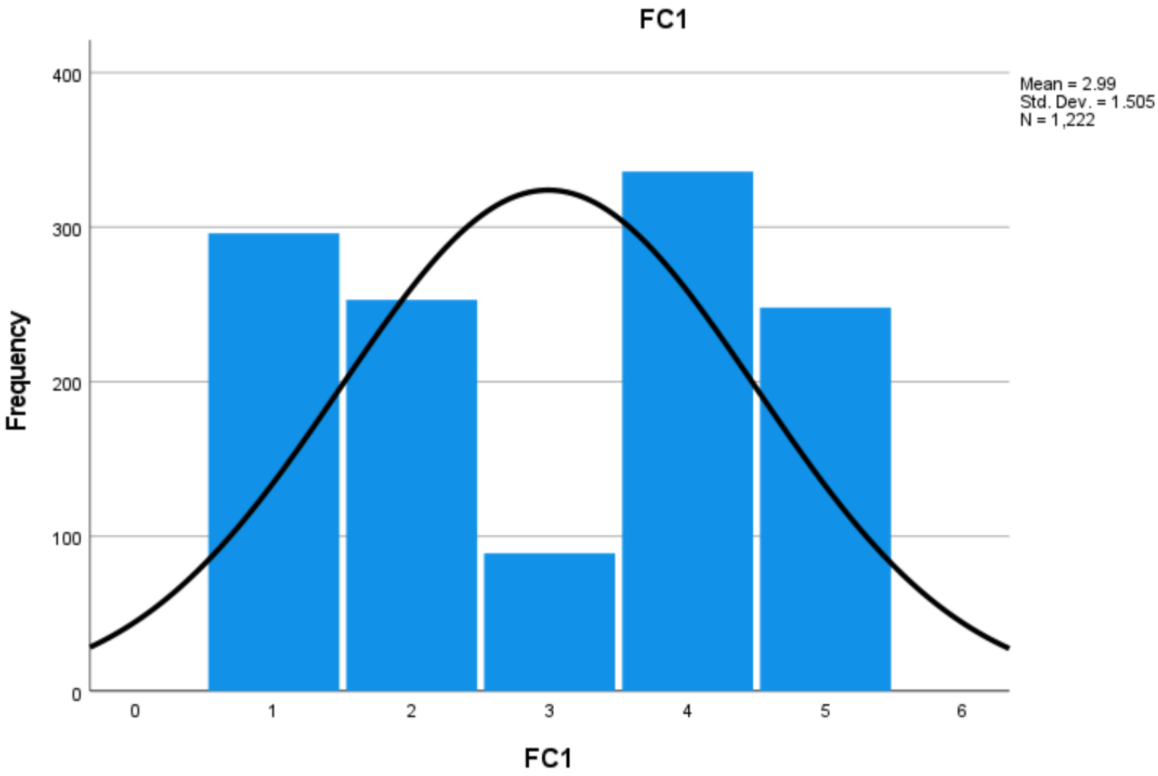
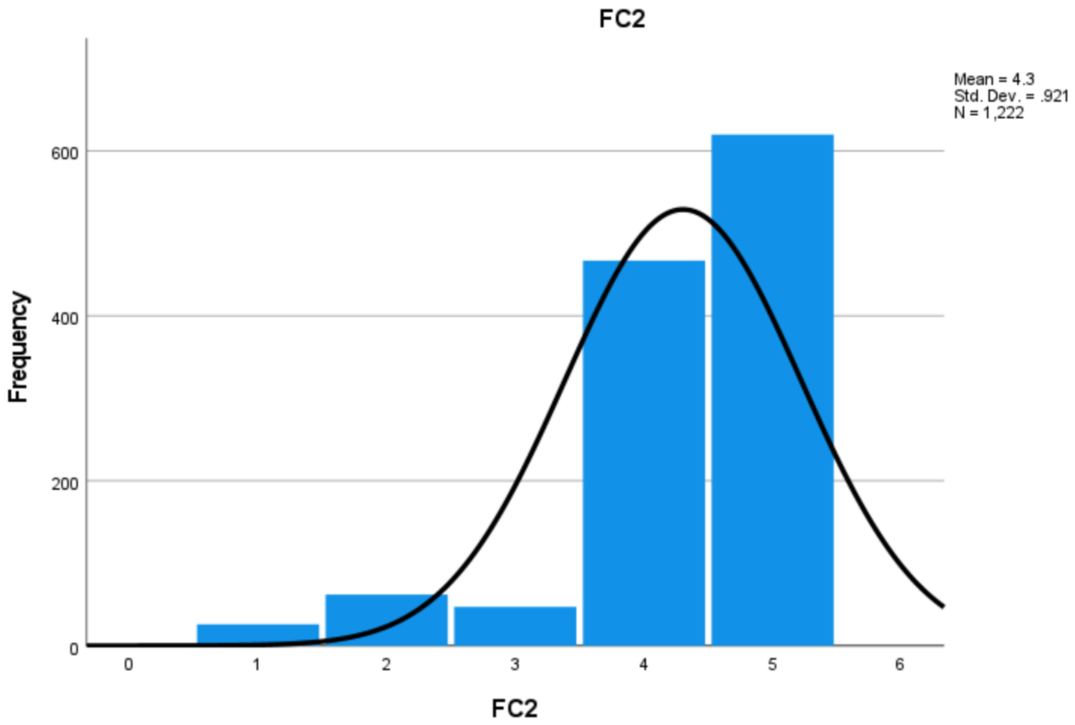
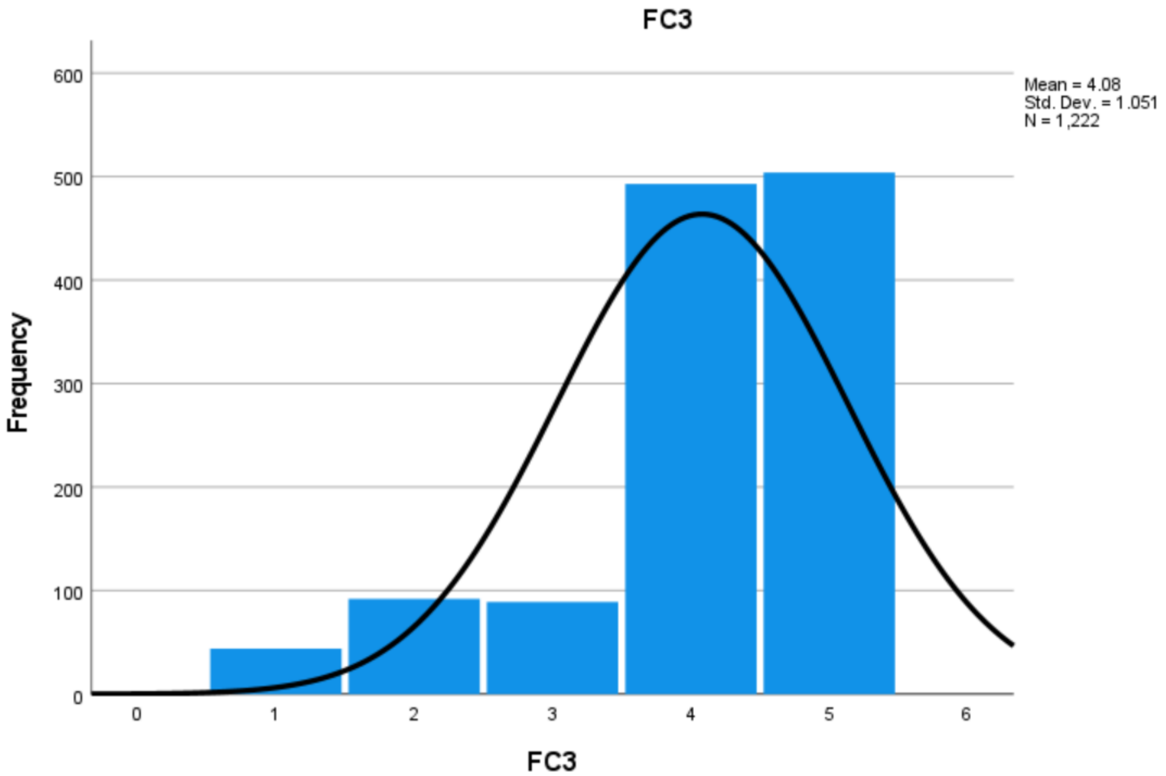
Annex J: Frequency of FC






FC3
Mean = 4.08
Std. Dev. = 1.051
N = 1,222
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100
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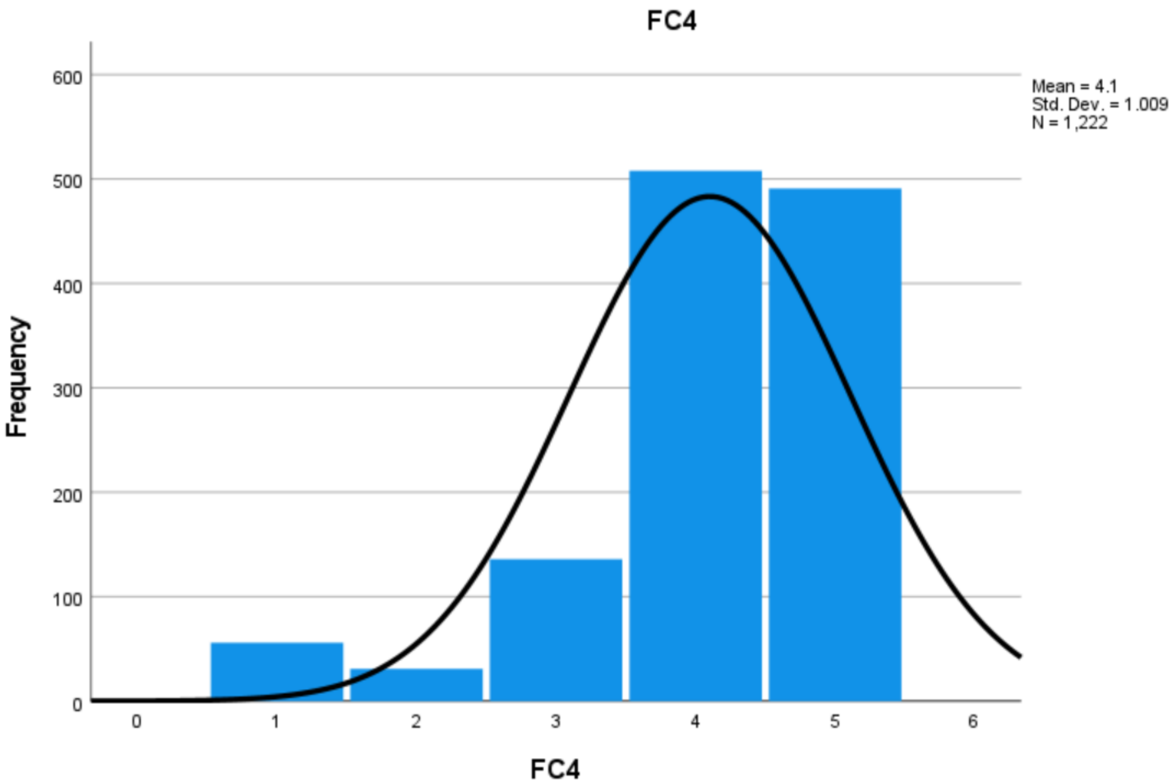
300
400
500
600
0
1
2
3
4
5
6
FC3


FC4
Mean = 4.1
Std. Dev. = 1.009
N = 1,222
Frequency
0
100
200
300
400
500
600
0
1
2
3
4
5
6
FC4