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Application of Mobile Health Services to Support Patient Self-Management of Chronic Conditions

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Abstract

Background: Chronic conditions are the leading cause of ill-health, disability and premature death, adding huge health and socioeconomic burden to the healthcare system. Although mobile health (mHealth) services have the potential to provide patients with a timely, ubiquitous, and cost-effective means to access healthcare services, to date, much remains to be revealed for their application in chronic condition management.

Aim: This doctoral project aims to comprehensively understand the application of mHealth services to support patient self-management of chronic conditions. This aim is achieved through four objectives: (1) to synthesise research evidence about health outcomes of applying mHealth services to support patient self-management of chronic conditions and the essential components to achieve these outcomes, (2) to determine the mechanism for applying mHealth services to support patient self-management of chronic conditions, (3) to explore critical factors and how these factors influence patients' intention to continuously use mHealth services, and (4) to apply the above findings to guide the design of a prototype mHealth service.

Methods: To increase the generalisability of the findings, three chronic conditions that could benefit from mHealth services were purposively studied to address the research objectives within the feasibility of available study sites and resources at different stages of the project. First, two literature review studies were conducted to achieve Objective 1. One was a systematic review to investigate health outcomes of mHealth services to support patient self-management of one chronic condition, unhealthy alcohol use, and the essential components to achieve these outcomes. The other was a rapid review on using behavioural theory to guide the design of mHealth services that support patient self-management of another chronic condition, hypertension. Second, two field studies were conducted to achieve Objectives 2 and 3, respectively. One was an interview study that explored patients' perceptions of a mHealth service to support their self-management of hypertension in China. The other was a questionnaire survey study conducted on the same site that explored critical factors influencing patients' intention to continuously use the mHealth service. Third, a clinician-led, experience-based co-design approach was implemented to apply the above-mentioned learning experience to the development practice of a mHealth service that supports patient self-management of obesity before elective surgery in Australia, achieving Objective 4.

Results: Literature reviews identify five structural components - context, theory, content, delivery mode, and implementation procedure - which are essential for mHealth services to achieve three health outcomes - behavioural, physiological, and cognitive outcomes. Inductive synthesis of the interview findings lead to a 6A framework that summarises the mechanisms for mHealth services: access, assessment, assistance, awareness, ability, and activation. Mobile health services provide patients with easy access to health assessment and healthcare assistance to increase their self-management awareness and ability, thereby activating their self-management behaviours. Questionnaire survey study finds that patients' intention to continuously use mHealth services can be influenced by the information quality, system quality and service quality by influencing their perceived usefulness and satisfaction with the mHealth services. Guided by Social Cognitive Theory, the developed prototype mHealth service provide patients with functions of automatic push notifications, online resources, goal setting and monitoring, and interactive health-related exchanges that encourage their physical activity, healthy eating, psychological preparation, and a positive outlook for elective surgery. The patients' requirements in two focus group discussions enabled the research team to improve the mHealth service design.

Conclusion: Mobile health services guided by behavioural theories can provide patients with easy access to health assessment and healthcare assistance to increase their self-management awareness

and ability, thereby activating their self-management behaviours. The effort for designing mHealth services needs to be placed on crafting content (to improve information quality), developing useful functions and selecting a proper delivery mode (to improve system quality), and establishing effective implementation procedures (to improve service quality). These will ensure patients' perceived usefulness and satisfaction with mHealth services, increase their intention to continuously use such services, thus supporting long-term patient self-management of chronic conditions. As demonstrated by the design case, the findings of this PhD project can be generalised to guide the design of other mHealth services that aim to support patient self-management of chronic conditions.

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Undertaking a PhD candidature has been a challenging but inspiring and exciting experience with a myriad of thoughts and ideas. Looking back on the hardship in my study pursuit, a tumult of feelings well up in my heart, whirling with images born of a multitude of impulses. This thesis would not have been possible without the assistance and support of many people, for which I would like to express my appreciation.

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Certification

I, Ting Song*, declare that this thesis submitted in fulfilment of the requirements for the conferral of the degree Doctor of Philosophy, from the University of Wollongong, is wholly my own work unless otherwise referenced or acknowledged. This document has not been submitted for qualifications at any other academic institution.*

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Ting Song

31st March 2021

Statement of the Thesis Style

In agreement with my supervisors, this thesis has been prepared by a compilation of the published/prepared journal articles that I have made a major contribution to my PhD journey. It has been compiled in accordance with "Higher Degree Research (HDR) Thesis by Compilation Guidelines at UOW".

List of Publications Included as Part of the Thesis

Published peer-reviewed journal articles

- Song, T., Qian, S. and Yu, P., 2019. Mobile health interventions for self-control of unhealthy alcohol use: systematic review. *JMIR mHealth and uHealth*, *7*(1), p.e10899.
- Song, T., Liu, F., Deng, N., Qian, S., Cui, T., Guan, Y., Arnolda, L., Zhang, Z. and Yu, P., 2021. A comprehensive 6A framework for improving patient self-management of hypertension using mHealth services: Qualitative thematic analysis. *Journal of Medical Internet Research*, *23*(6), p.e25522.
- Song, T., Deng, N., Cui, T., Qian, S., Liu, F., Guan, Y. and Yu, P., 2021. Measuring success of patients' continuous use of mobile health services for self-management of chronic conditions: Model development and validation. *Journal of Medical Internet Research*, *23*(7), p.e26670.
- Song, T., Yu, P., Bliokas, V., Probst, Y., Peoples, G.E., Qian, S., Houston, L., Perez, P., Amirghasemi, M., Cui, T. and Hitige, N.P.R., 2021. A clinician-led, experience-based co-design approach for developing mHealth services to support the patient self-management of chronic conditions: Development study and design case. *JMIR mHealth and uHealth*, *9*(7), p.e20650.

Published peer-reviewed book chapter

- Song, T., Qian, S., Cui, T. and Yu, P., 2019. The use of theory in mobile health interventions for patient self-management of chronic diseases. *Studies in Health Technology and Informatics, 264,* p.1982.

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List of Abbreviations

A-CHESS: Alcohol-Comprehensive Health Enhancement Support System

AUD: alcohol use disorder

AUDIT: alcohol use disorders identification test

AUDIT-C: alcohol use disorders identification test for consumption

AVE: average variance extracted

BASICS-Mobile: Brief Alcohol and Smoking Intervention for College Students via Mobile

BP: blood pressure

BrAC: breath alcohol concentration

COM: Community Organisation Model

DIT: Diffusion of Innovation Theory

eBAC: estimated blood alcohol concentration

FAST: fast alcohol screening test

IS: information systems

ISLHD: Illawarra and Shoalhaven Local Health District

IVR: interactive voice response

mHealth: mobile health

MMAT: Mixed Methods Appraisal Tool

MRC: Medical Research Council

PLS-SEM: partial least square structural equation modelling

RSOD: risky single-occasion drinking

SCT: Social Cognitive Theory

SD: standard drink

SDT: Self-determination Theory

SMS: short message services

TM: Transtheoretical Model

TPB: Theory of Planned Behaviour

UAU: unhealthy alcohol use

VIF: variance inflation factor

Chapter 1

General Introduction

1.1 The Rationale of This Thesis

With population ageing and improvements in health services, there has been increasing attention to managing chronic conditions in the developed countries [1, 2]. Chronic conditions are also known as chronic diseases, degenerative diseases, or non-communicable diseases, such as hypertension, diabetes, obesity or substance use. Although slow in progression and not infectious, chronic conditions are long-lasting and have persistent detrimental effects on the bearers' health and wellbeing [1, 3]. They cause 41 million deaths each year, accounting for 71% of all global deaths, surpassing all other causes combined [3]. The morbidity of chronic conditions is also accelerating, pervading every region and the entire socioeconomic class worldwide. It is estimated that by 2030, the number of global deaths from chronic conditions will increase from 38 million in 2012 to 52 million, leading to an economic burden of 47 trillion US dollars per year [4, 5]. More terrifying is that one-third of adults worldwide live with two or more chronic conditions, known as multiple chronic conditions, imposing disproportionate burdens on health and cost [6]. Due to the tremendous health and socioeconomic impacts on patients' quality of life, not only physically but also mentally and socially, chronic conditions are the main health challenges facing humanity in the 21 century and have become a priority for action by governments and health authorities.

Once it starts, a chronic condition usually persists throughout a person's life and requires life-long management with the joint efforts of patients and healthcare providers [1, 3]. Routine in-hospital treatment includes surgery, physiotherapy, psychotherapy, radiotherapy and chemotherapy [7]. However, since chronic conditions are not immediately life-threatening and lack medical resources for their management, most patients are outpatients and do not require hospitalisation [3, 7, 8]. Instead, patients usually need to carry out long-term and systematic self-management outside the hospital. Therefore, increasing attention has been focused on strategies, methods and techniques to support community-dwelling patients to self-manage chronic conditions and maintain independence and quality of life. Recent years have seen a steady paradigm shift in chronic condition management from a paternalistic doctor-dominated approach to a patient-central self-management and care approach, cooperating with their healthcare providers [9].

The four major prevalent chronic conditions are cardiovascular disease, cancer, chronic respiratory disease, and type-2 diabetes, accounting for 60% of global deaths from chronic conditions [10]. Although unique in their own characteristics and care needs, and sometimes co-occur, these chronic conditions are often caused by certain common risk factors, which include genetic risk factors (such as age and gender), biological risk factors (such as high blood pressure, high blood cholesterol, and overweight), and behavioural risk factors (such as tobacco use, physical inactivity, unhealthy diet, and unhealthy alcohol use) [11-14]. In theory, as long as these risk factors are controlled in a well-integrated manner, self-management will be effective in restraining chronic condition symptoms.

Chronic condition self-management paradigms include initialising a treatment program, taking medication/self-injection as prescribed, and reducing modifiable behavioural risk factors [15-18]. In addition, patients also need to regularly record vital signs at home [16]. For example, they can identify their own characteristics and patterns in their health records and share the vital sign information with the clinicians to help them monitor their conditions and provide suitable treatment and guidance on self-management plans, such as adjusting the type and dosage of medicine as needed. Therefore, adherence to a self-management plan is essential to preventing the deterioration of chronic conditions and maintaining health and wellbeing. However, it has never been easy nor satisfactory for many patients to adhere to self-management plans and control chronic conditions because it requires persistent effort to maintain ongoing management [15, 19].

Therefore, more innovative and multifaceted health services are helpful to support patients to continuously self-manage chronic conditions.

With the proliferation of the Internet and the penetration of mobile technologies into all walks of life, it is the right time to use mobile devices to support people's health, wellbeing, and self-management of chronic conditions [20]. This is because mobile devices, such as smartphones, have provided us with a unique opportunity for monitoring our vital signs anytime, anywhere to prevent or manage these conditions proactively. Mobile health (mHealth) refers to the use of mobile devices, such as mobile phones, personal digital assistants or other wireless devices, to deliver medical or public health services [20]. Due to the limited human resources available for delivering continuous healthcare services for community-dwelling patients suffering from chronic conditions, mHealth services are increasingly considered by the decision-makers and patients alike as a potential alternative solution in providing the same quality but low-cost services to address the challenges for chronic condition management [21].

Despite the increasing acceptance and use by patients to support their self-management of chronic conditions [22-25] and the numerous success stories to date [26-33], the effectiveness of mHealth services is uneven without clear reasons [34-37]. Patient adherence to these services is yet unsatisfactory [38-40]. There is a pressing need to fully understand the application of mHealth services to support patient self-management of chronic conditions. The key research questions are what are the essential components of these mHealth services that support patient self-management of chronic conditions, how they are applied, what are the outcomes of the application, and which factors may influence patients' intention to continuously use these mHealth services.

1.2 Aims and Research Objectives

This doctorate aims to comprehensively understand the application of mHealth services to support patient self-management of chronic conditions. Donabedian's healthcare quality assessment framework, which underpins measurement of healthcare quality for improvement from three aspects, i.e. structure, process and outcome, is used to guide this research [41]. This framework has been widely used to comprehensively assess the quality of electronic medical records for aged care services [42], telehealth for the management of chronic conditions [43], and inpatient portals for accessing health information and interacting with clinicians [44].

In Donabedian's original framework, the structure concerns the environment for providing healthcare services, such as hospital buildings, staff, finances, and equipment [41]. In this study, the structure specifically refers to the components of mHealth services, such as content and delivery mode. Outcome originally refers to the impact of medical care on the health of patients and populations [41]. In this study, the outcome refers to the benefits of mHealth to support patient self-management of chronic conditions, such as improvements in vital signs, cognitions or behaviours. Therefore, the first research objective is

1. *To synthesise research evidence about health outcomes of applying mHealth services to support patient self-management of chronic conditions and the essential components to achieve these outcomes.*

To fully understand the state-of-art and to stay at the forefront, as well as to collect and analyse collective evidence in the study field [45], this doctorate project starts with a systematic literature review of mHealth services for support patient self-managing a specific type of chronic condition, unhealthy alcohol use [46]. This ensures the project benefits from a relatively comprehensive and systematic review of mHealth services to support self-management in the context of general chronic conditions [37, 47-49]. The systematic review suggests that theory-guided mHealth service development and implementation is more effective, despite a lack of evidence about the use of theory to guide the design, implementation and evaluation of mHealth services. Therefore, a rapid review is conducted to explore which theories and how they have been used to guide the mHealth services that support patient self-management of chronic conditions, as answers to part of Objective 1.

In Donabedian's framework, the process includes all actions that constitute health care. In this study, it refers to the implementation of the mHealth services and the mechanisms used to facilitate the implementation to achieve the desired outcomes, such as mHealth app usage and patient education. Therefore, the second objective of the project is:

2. *To determine the mechanism for applying mHealth services to support patient self-management of chronic conditions.*

As patient self-management of chronic conditions needs a long-term effort, the success of mHealth services is contingent upon patients' continuous use of the services to achieve long-term health outcomes. Therefore, the third objective is

3. *To explore critical factors and how these factors influence patients' intention to continuously use mHealth services.*

To achieve the above two objectives, the project adopted a mixed-method approach in the empirical field studies. Constraint by accessibility to the potential study sites and available resources, the study setting of our exploratory field research is in Ningxia Province, China, and the chronic condition supported by the mHealth service is hypertension. The data collection methods include semi-structured in-depth interview [50, 51] and questionnaire survey [52]. The data analysis methods include qualitative thematic analysis [53] and quantitative partial least squares regression [54].

To prove the feasibility of the inducted findings to guide the design of mHealth services that support patient self-management of chronic conditions, the last objective of the project is:

4. To apply the above findings to guide the design of a prototype mHealth service.

To prove the feasibility and generalisability of theory-guided mHealth service development, Social Cognitive Theory was selected to guide the design and development of a prototype mHealth app to support patients with obesity to lose weight and improve fitness before elective surgery in Australia, within the project team's accessibility to the potential study sites and available resources. A clinician-led experience-based co-design approach with multi-disciplinary healthcare professionals is undertaken for the design of this prototype mHealth service, including a panel discussion, literature review, intervention mapping, focus group discussions and thematic analysis [62].

1.3 Thesis Structure

This thesis is comprised of eight chapters: a general introduction (Chapter 1), a general literature review (Chapter 2), five original research studies (Chapters 3-7), which addresses Objectives 1 to 4, and a general conclusion (Chapter 8).

Following this general introduction of the project, Chapter 2 syntheses and analyses the relevant evidence on mHealth services to support patient self-management of chronic conditions. This chapter starts with introducing three types of risk factors for chronic conditions at the individual level (i.e., genetic factors, behavioural factors, and biomedical factors), suggesting that only the latter two factors are manageable by the patients. After briefing common theoretical underpinnings of chronic condition management, including Chronic Care Model, Stanford Chronic Disease Self-Management Model, Individual and Family Self-Management Model, and Transitional Care Model, the key stakeholders - healthcare providers and patients - for chronic condition management are identified, as well as their responsibilities, common approaches used and the challenges they face in chronic condition management. This is followed by reviewing the current status of mHealth services to support patient self-management of chronic conditions. A major driving force to introducing mHealth service to support patient self-management of chronic conditions is the limited human resources available for delivering continuous healthcare services for community-dwelling patients suffering from chronic conditions. Mobile health services offer an alternative means for the provision of the same quality yet low-cost healthcare services. This is followed by reviewing the research evidence about the application, adoption and effectiveness of mHealth services to support patient self-management of chronic conditions, where the research gaps are identified. The chapter ends with a description and justification of the potential methods that can be used to address these research gaps. A detailed review of each research question area is presented in the introduction section of each relevant chapter (Chapters 3-7).

Chapter 3 describes a systematic review of using mHealth services to support patient self-management of unhealthy alcohol use. The review addresses Objective 1 by summarising the five structural components of mHealth services to support patient self-management of chronic conditions - context, theoretical base, content, delivery mode, and implementation procedure. The three health outcomes likely to be brought by using mHealth services are physiological outcomes, behavioural outcomes, and cognitive outcomes. The review also identifies a limitation of the inadequate report about the use of theory to design, implement and evaluate mHealth services to support patient self-management of chronic conditions, paving the way to Chapter 4, a rapid review to explore what and how the theories have been used to guide the mHealth services that support patient self-management of chronic conditions. This systematic review has been published in JMIR mHealth and uHealth, so the chapter adopts the published paper format.

Chapter 4 describes a rapid review to investigate the reported use of theory in mHealth services for self-management of another chronic condition, hypertension. This review further explores one of the essential components of mHealth services, theory, reported in Chapter 3. It finds that theories have been used to design and implement mHealth services that support patient self-management of hypertension, leading to the enrichment of the evidence base and improved effectiveness of these healthcare services. However, there is inadequate research that provides a detailed account of how theory has been implemented in mHealth services to support patient self-management of chronic conditions, which has limited the replicability of these studies. The review has been published as a book chapter in *Studies in Health Technology and Informatics* and presented in the *17th World Congress of Medical and Health Informatics (MedInfo 2019) in Lyon, France*.

Chapter 5 reports an empirical qualitative study about the mechanism of mHealth services to support patient self-management of chronic conditions. Twenty-two community-dwelling patients with hypertension in Ningxia Province, China, are interviewed to explore their perceptions about a mHealth service named "Blood Pressure Assistant" to support their self-management of hypertension. Their perceptions are summarised into a 6A framework: access, assessment, assistance, awareness, ability and activation. The portability of mobile phones and digitisation of information enable the mHealth service to provide hypertensive patients with low-threshold access to health assessment and healthcare assistance. The assessment results, i.e. vital signs and self-management behaviours, give the patients real-time awareness of health conditions and self-management performance. In particular, abnormal results, such as deterioration of vital signs or lack of self-management behaviour records, can also be fed back to healthcare providers to provide the patients with assistance. Healthcare assistance includes health education and reminders of self-management behaviours. Health education assists the patients in improving their awareness of the importance of self-management and their ability, i.e. knowledge and skills, to perform self-management behaviours. The reminders assist the patients in overcoming lapses of memory. Improvement of self-management awareness, ability, and reminders, together, activates their self-management behaviours. The findings lay a theoretical foundation for further research to optimise mHealth services and support the design, implementation and evaluation of mHealth services to support patient self-management of chronic conditions. This study has been published in the *Journal of Medical Internet Research*, so the chapter adopts the published paper format.

Chapter 6 describes an empirical quantitative study about the factors influencing patients' continuous use of mHealth services to support their self-management of chronic conditions. Although mHealth services have been gradually introduced to support patient self-management of chronic conditions, the success of these services is contingent upon patients' continuous use of them. This chapter describes the development of a model to measure the success of patients' continuous use of mHealth services to support patient self-management of chronic conditions through integrating two classic models in IS research - Information Systems Continuance Model and Information Systems Success Model. A questionnaire survey study is conducted in patients who use the same mHealth service reported in Chapter 5 to test the model. The patients' continuous use intention is found to be significantly influenced by their perceived health status, perceived usefulness and user satisfaction with the mHealth services. Information quality, system quality and service quality have a significant positive influence on perceived usefulness, but not on user satisfaction. Perceived usefulness has a significant positive influence on user satisfaction. This study has been published in the *Journal of Medical Internet Research*, so the chapter adopts the published paper format.

Chapter 7 presents a clinician-led, experience-based co-design approach implemented to apply the above-mentioned learning experience to the development practice of a mHealth service that supports patient self-management of obesity in their preparation for elective surgery in Australia. The design is guided by Social Cognitive Theory and implemented the findings reported in the previous four chapters. The mHealth app is pilot tested through two focus group discussions of patients with obesity. This provides preliminary validation of the feasibility of applying the research findings into mHealth app design. This study has been published in the *JMIR mHealth and uHealth*, so the chapter adopts the published paper format.

Chapter 8 provides a general conclusion of the thesis. It summarises the findings reflecting on the research aim and objectives, the contribution to knowledge, implications for practice, and limitations. The thesis concludes by a projection of the future research directions in designing and implementing mHealth service to support patient self-management of chronic conditions.

Chapter 2

Literature Review

Forward

The previous chapter introduced the rationale for this PhD project, including the research aims and questions and how these are addressed through the ensuing chapters. This chapter focuses on reviewing the relevant bodies of literature on the important and interrelated areas in self-management of chronic conditions using mHealth services. The aim is to provide a theoretical base for this PhD research project. These include (1) risk factors for chronic conditions; (2) current status of chronic condition management; (3) mHealth services to support patient self-management of chronic conditions; (4) research gap; and (5) the potential methods that can be used to address the research gap.

2.1 Risk Factors for Chronic Conditions

A person's health status can be influenced by various factors. Some factors function at the individual level, such as genetic make-up or health-related behaviours, while others function at the societal level, such as the provision of health services, vaccination programs or a healthy environment. The factors that affect health in a negative way are known as risk factors [13, 55]. They can increase the likelihood of suffering from chronic conditions, accelerate the deterioration of the existing chronic conditions, or hinder the management of these conditions. There are three major personal risk factors for chronic conditions: genetic factors, behavioural factors, and biomedical factors.

2.1.1 Genetic Risk Factors

Genetic risk factors for chronic conditions are always non-modifiable, i.e. not within a person's control or unmanageable. These risks include age, gender, heredity, and disability status. For example, men and women have different symptoms of a heart attack [56], which can be explained by the difference in coronary artery size between men and women [57]. Inheritance may increase the susceptibility of the offspring to chronic conditions, which will adversely affect a person's health [58]. For example, it was found that compared with adolescents without parental hypertension, those with parental hypertension have higher risks of suffering from hypertension [59]. Therefore, genetic factors are definitely one of the determinants for the onset of chronic conditions. But, for all that, they are not believed to be the major causes of such conditions [60].

2.1.2 Behavioural Risk Factors

Behavioural risk factors are mainly health-related behaviours, including unhealthy diet, physical inactivity, tobacco use, and unhealthy alcohol use [3, 13, 55]. Although a person's behaviour may be affected by multiple external determinants such as social, economic, cultural, and financial status, in most cases, controlling the behaviours lies with that person. Therefore, behavioural risk factors are most prone to modification for individuals and are usually the main focus of chronic condition management program and health promotion activities. Behavioural risk prevention is often the entry point of various intervention services for chronic condition management.

Unhealthy diet

With the acceleration of urbanisation and the increase in processed foods, people's eating habits have undergone undesirable changes [61]. These include overeating fat and greasy food, high-flavour food, i.e. free sugar, salt/sodium and spicy food, and not eating enough fruits, vegetables, legumes (e.g. lentils and beans), nuts, and other dietary fibre, such as whole grains (e.g. unprocessed maise, millet, oats, wheat and brown rice).

Diet and nutrition are well known to play a vital role in our health and wellbeing throughout the human life course. A healthy diet can prevent many chronic conditions, such as obesity, cancer, type 2 diabetes and heart disease, and improve overall health [62]. They are also closely related to the onset of mental health problems such as depression, mood disorders and anxiety [63]. Moreover, the "quantity" of nutrition intake is also significant. For example, salt is an important nutrient for the human body. Long-term lack of salt intake can cause neurological disease and even death, but too much salt can cause high blood pressure and other chronic heart and kidney diseases [62, 64]. Therefore, improving diet is an integral part for patients to self-manage chronic conditions.

Physical inactivity

Physical activity is a bodily movement produced by skeletal muscles that require energy expenditure. Approximately 3.3 million people worldwide die each year due to physical inactivity, making it the fourth leading cause of mortality [63, 65]. Adequate physical activities on a regular basis can reduce the risk of incidence, recurrence, progression, and premature mortality of chronic conditions, improve the control of vital signs, and improve the patients' quality of life [66, 67]. In chronic condition management programs, the type, intensity, frequency and duration of physical exercise recommended by the scientific guidelines have been proven to be effective and sustainable [68, 69]. Although only a few people actually follow or insist on conducting physical activities, the epidemiological benefit of these programs is considerable. For example, studies have found that avoiding sedentary, even small doses of physical exercise can protect health and reduce the risk of premature death by about 22% [70].

Tobacco use

Tobacco use is one of the greatest public health challenges the world has ever faced. All types of tobacco are harmful and have no safe level of exposure [2, 55]. Tobacco use causes over 8 million deaths worldwide each year. Of these, more than 7 million died from direct smoking, while about 1.2 million died from non-smokers exposed to second-hand smoke [71]. As smoking may cause cancer, cardiovascular disease, diabetes, and chronic obstructive pulmonary disease, tobacco use control has far-reaching significance for self-management of chronic conditions. However, on the positive side, the total global tobacco use has dropped from 1.397 billion in 2000 to 1.337 billion in 2018 [72]. This shows that under the vigorous government and media champion against tobacco use, people's awareness of the harm of tobacco use has increased, which also demonstrates the important role of health education for behavioural modification.

Unhealthy alcohol use

Differing from tobacco use, alcohol use has both beneficial and detrimental impacts on diabetes, ischemic stroke, and ischemic heart disease, depending on the overall volume of alcohol consumed and, in the case of ischemic diseases, consumption patterns [73]. Unhealthy alcohol use is also a major risk factor for many chronic conditions, such as high blood pressure, heart disease, stroke, liver disease, and digestive problems [5, 74]. The International Classification of Diseases-10 codifies 25 types of chronic conditions which are attributable to alcohol use [73]. Therefore, unhealthy alcohol use adds a significant burden on the global healthcare system, which should be the target of intervention services.

2.1.3 Biomedical Risk Factors

Biomedical risk factors, also known as metabolic risk factors or intermediated risk factors, contribute to four key metabolic changes that increase the risk of chronic conditions: raised blood pressure, overweight/obesity, raised blood glucose level, and abnormal blood lipid, in descending order of global attributable mortality [13, 55]. Although these four metabolic changes are not entirely modified by behaviours, they are greatly affected by health behaviours and show differences among different groups of people. If these metabolic changes are outside the normal range for a long time, they are regarded as chronic conditions. Kardia et al. find that family history is a good predictor of individual disease risk because family members usually share the unique genomic makeup and environmental interactions [75]. The genetic variation inherited in the family can directly or indirectly cause the onset of chronic conditions.

2.2 Current Status of Chronic Condition Management

This section will start with the discussion on various theories of chronic condition management, and review the common chronic condition management stakeholders and approaches and the challenges they face.

2.2.1 Theoretical Underpinnings of Chronic Condition Management

There are a large number of chronic condition management models in the literature, such as Chronic Care Model, Stanford Chronic Disease Self-Management Model, Individual and Family Self-Management Model, and Transitional Care Model, which consider different aspects of chronic condition management.

The Chronic Care Model, as one of the classic models in this field, provides guidance for shifting the focus from the acute onset health system to the one that is required for effective long-term health care, providing a systematic, organisational care framework for patients with chronic conditions in primary care settings [76]. The model emphasises the role of patients in managing chronic conditions. The key component "self-management support" requires structural changes in the care of patients with chronic conditions, introducing a patient-centred care model with the participation of nurses and social workers.

The Stanford Chronic Disease Self-Management Model further studies the importance of self-efficacy on the basis of the Chronic Care Model, which emphasises providing patients with the self-efficacy and skills needed to best self-manage their chronic conditions [77]. The goal is to support patients to better understand chronic conditions through learning six self-management techniques: problem-solving, decision making, use of resources, doctor-patient relationship establishment, and action plan development.

The Individual and Family Self-Management Model shifts the focus from primary care settings back to the home, where patients with chronic conditions usually spend the longest time [78]. The model puts forward three dimensions of self-management: context, process and outcomes and extends the particularity of the process to include knowledge and beliefs, self-regulation skills and abilities, and social convenience. It further subdivides the outcomes into proximal and distal ones. Proximal outcomes include all self-management behaviours that directly target symptoms or risk control. Distal outcomes extend from chronic condition itself to more general health, including health status, quality of life and health cost, which are closely related to the successful achievement of the proximal outcomes. This model emphasises the importance of families for caring and patient's chronic condition management.

Patients with chronic conditions do not always stay in the hospital or stay at home. They typically receive healthcare services from different healthcare providers and frequently move throughout various healthcare settings. Therefore, the Transitional Care Model focuses on improving the healthcare process and outcomes for the high-risk, high-cost, and high-volume patient groups [79]. The transitional Care Model addresses gaps in the transition of care settings, i.e., hospital-to-home care, from long-term care to palliative care, and meets the needs of patients for long-term care [80]. The model fulfils the patients' needs for medication adherence and persistence, assessment and assistance for health literacy, monitoring and problem solving, and promoting behavioural changes to achieve optimal disease management.

2.2.2 Key Stakeholders and Common Approaches to Support Patient Self-management of Chronic Conditions and Their Challenges

Effective chronic condition management is inseparable from healthcare providers. They are generally a multidisciplinary care team consisting of doctors, nurses and pharmacists with clinical and behavioural skills. These healthcare providers can ensure that the key components of chronic condition management are competently performed, including patient management, medication prescription and supervision, health education and consultation, and intensive follow-up. However, studies have found that patients always play a passive, subordinate role in chronic condition management due to a variety of reasons, including a lack of health awareness and literacy, misleading by the media and industry, and paternalistic and medicalised attitudes of some healthcare providers.

In addition, there is a serious asymmetry between patients with chronic conditions and medical resources. The burden of meeting the needs for the growing population adds burden to the already over-stretched medical services, i.e., requesting adding manpower, service facilities and medical equipment, the demand for which is difficult to meet for the acute care services, let alone long-term care for chronic conditions. Moreover, the distribution of medical institutions and medical resources of different sizes is also asymmetrical. High-quality medical resources are increasingly concentrated in large healthcare institutions, and the resources of primary healthcare institutions are often lagging behind. Therefore, the management of chronic conditions has to be gradually shifted from the care model centred on healthcare providers and hospitals, which puts patients in the role of passive recipients to patients themselves, in which patients take an increasingly proactive role and responsibility for active participation in keeping with the reality of chronic conditions, i.e. self-management.

The term self-management has been first introduced by Thomas Creer, which means patients are active participants in their own treatments [81]. Thorne et al. define it as individuals gain the ability and process to control their chronic conditions instead of relying solely on their healthcare provides [82]. Wilkinson and Whitehead expanded its definition from the individuals to their families, communities, and healthcare providers to co-manage symptoms, treatments, lifestyle changes, and outcomes of chronic conditions [83]. In this thesis, self-management is defined as a dynamic and continuous process for an individual to execute daily action of the management of symptoms, treatment, lifestyle modification in order to improve an existent chronic condition. The actions include plan, implement healthy behaviour, monitor their health conditions, physiological, behavioural and cognitive responses, evaluate and modify the action to maintain a satisfactory quality of life [37].

There are various approaches for healthcare providers to provide support for patients to self-manage chronic conditions. These include assessment, information and health education, and motivation [84-88]. A health assessment is a crucial first step to ensure that patients believe that self-management support can help them manage their chronic conditions well and improve wellbeing so that they can consciously initiate the healthy behaviours required for self-management of these conditions [85, 86]. It is well known that effective healthcare for self-management is more than just telling the patients what to do, but also providing relevant information and educational material to improve patients' knowledge and health literacy [84]. The common self-management support for health education includes a group-based approach, an individualised approach, or a combination of the two, often supplemented by printed materials, emails, videotapes. Motivation is another key to changing behaviour. Although many patients are striving to achieve the self-management goals, the large number of self-management tasks may make them feel unable to keep up with the daily routine or management demands of chronic conditions [87, 88]. At this time, patients can usually give very reasonable explanations for why they have not taken effective self-management behaviours, such as lack of motivation, fear of failure, or distrust. As a common method of encouraging patients, motivational interviews involve the use of evidence-based professional guidance to motivate behavioural changes in patients with chronic conditions [89-95]. Health providers aim to use patient engagement strategies to develop towards specific health goals, thereby improving the health outcomes of patients.

2.3 mHealth Services to Support Patient Self-Management of Chronic Conditions

2.3.1 Overview of mHealth Services

Mobile health refers to the use of mobile devices, such as mobile phones, tablet computers, and personal digital assistants, to provide medicine, public health, and health services [20]. The purpose of mHealth is to improve population health outcomes, quality, safety, access, and efficiency of health services and health research.

As a rapidly expanding subset of eHealth, mHealth focuses on the utilisation of mobile and wireless information and communication technologies to support the achievement of health objectives. The applications in mHealth include, but are not limited to, real-time voice and short message service (SMS) provided by mobile phones, more complex functionalities and applications based on general packet radio service, third- and fourth-generation mobile telecommunications, global positioning system, sensor and Bluetooth technologies provided by smartphones, or other smart devices. Although mHealth cannot solve all problems in healthcare, it can lead to major advances by improving access to healthcare services and decision making [96].

Mobile health services have been widely used in disease prevention, community and clinical health data collection, disease diagnosis and treatment. Using mHealth devices, healthcare professionals can (1) provide patients with preventative and educational information before or at the early stage of their disease; (2) understand patients' needs and detect problems quickly by reading clinical health data of patient collected by mHealth devices; (3) identify the cause of health deterioration; (4) provide healthcare interventions for patients; (5) improve the decision-making process as well as healthcare outcomes. For example, a mHealth app, Stroke Emergency Mobile (STEMO) could conduct a pre-hospital diagnosis to determine the stroke type quickly and accurately so as to improve triage of patients with cerebrovascular events to specialised hospitals (Wendt et al. 2015). Lim et al. (2011) found that HbA1c level was significantly improved through SMS-enabled diabetes mellitus education for diabetic patients. Mobile medical services can also play an important role in emergencies because they can help speed up certain processes, including event detection, patient information acquisition, and healthcare decision-making support. For example, Microsoft HealthVault can enable users to create health records specifically for unexpected hospital visits. It will notify first responders when an emergency happens [97].

Mobile health services have been applied globally in supporting patient self-management of the common chronic conditions, including asthma, cardiac rehabilitation, congestive heart failure, chronic lung diseases, chemotherapy symptoms, diabetes, HIV, hypertension, coronary artery disease, and weight loss [48]. These services are particularly useful for providing a similar level of health care to patients living in remote communities and rural regions as their city counterparts without extra cost. It can also enable the shift of investment in healthcare from treatment to prevention of age-related diseases, which is a long-lasting goal of population health [98]. For example, it can be used to integrate high-quality medical resources across borders to improve disease prevention and treatment. This could enable patients in underdeveloped regions to receive better healthcare services [99]. Healthcare professionals can also use such services to provide patients with healthcare services, to access patients' health/medical records, to utilise computerised physician order entry, and to prescribe/adjust medications electronically 24 h a day, 7 days a week.

With the increased capability to support patient self-management of chronic conditions, such as tracking health records, acquiring relevant information, communicating with healthcare providers or peers, or being reminded about health status, mHealth fits with the emerging patient-centred healthcare model [100, 101]. As most patients plagued by chronic conditions are older people, they face high risks of social isolation and poor health conditions; therefore, mHealth is promising to meet their need for innovative solutions to empower them to self-manage their own health and function and enable them to age at home independently instead of being placed in institutions at the end of their lives. These developments have been accelerating the applications of smartphones and mHealth services in various healthcare areas [102].

2.3.2 Characteristics of the mHealth Services to Support Patient Self-Management of Chronic Conditions

Davis et al. summarise four essential characteristics of mHealth that must be met for the successful design, implementation, and adoption of mHealth services that will be accepted and used by patients in self-management of chronic conditions [103]. They are (1) the penetration into or adoption by patients, (2) the availability and form of apps, (3) the availability and form of wireless broadband access to the Internet, and (4) the fit with individual needs and preferences.

Penetration into or adoption by patients is essential for the visibility and viability of mHealth. Despite the popularity of mobile phones and the purpose of mHealth, to date, there is a lack of adoption and use of mHealth services, especially in the older population [104]. The availability and form of apps include functionalities for data acquisition, transfer and analysis, ease of user access to the system, and connection to other health information systems [105]. The availability and form of wireless broadband access are vital to device connectivity and performance of data communication in mHealth services. The fit with individual needs and preferences is important not only to support personalised medicine or public health interventions but also for reducing the delay of communications [103].

2.4 Research Gap

Recent studies about the patient use of mHealth services to support their self-management of chronic conditions have focused either on their acceptance and adoption of such services [23-25, 106-115], or their effectiveness of condition control [38, 116-118] and adherence [38, 39, 119, 120]. However, none of these studies has found sound evidence about clear health outcomes of these mHealth services, nor have they identified the essential components of effective mHealth services. This knowledge gap has hindered the effective adoption and use of mHealth services in public health prevention and intervention programs to support patient self-management of chronic conditions.

Therefore, the first research question is:

> *Research Question 1. What are the health outcomes of mHealth services to support patient self-management of chronic conditions and the essential components of mHealth services to achieve these outcomes?*

Empirical evidence suggests that mHealth services can better assist the patients to control chronic conditions than the conventional face-to-face care model [121-126]. However, Alessa et al. found that only 30 out of 186 (16%) apps were likely to be more effective in supporting patient self-management of chronic conditions [34]. There was not enough information nor criteria to determine the effectiveness of mHealth services and mechanisms for achieving effectiveness. Therefore, the second research question is:

> *Research Question 2. What is the mechanism for mHealth services to support patient self-management of chronic conditions?*

Prior studies on patients' use of mHealth apps have focused on patient acceptance and initial use of these apps [106-115], only a few studies have focused on the continuous use of mHealth services beyond the initial stage of adoption and usage [127-130]. Some of these continuous use studies only examine the mHealth services for general healthcare, such as appointment and health consultation, instead of patient self-management of chronic conditions [127, 128, 130]. Cho develops and tests a model to explain the mechanism that determines the continuous use intention of mHealth services in Korean adults for general health care support. He finds that continuous use intention is influenced by confirmation of the primary expectation of mHealth apps but does not specify the content of the expectation [130]. Lee et al. find that patients' intention to continuously use mHealth service is closely associated with their regular use of self-monitoring function; however, they do not further explore the relationship between these two constructs [129]. To date, there has been little theoretical research on factors influencing patients' continuous use of mHealth services to support their self-management of chronic conditions. To fill this gap, the third question is

> *Research Question 3. What are the critical factors, and how these factors influence patients' intention to continuously use mHealth services to support their self-management of chronic conditions?*

Despite their increasing popularity, the reported effectiveness of mHealth services for self-management of chronic conditions is mixed [131-135]. The frequency with which large numbers of such services enter the market, coupled with the limited time that professional clinicians have available, has inhibited clinician participation in mHealth app design or evaluation [133]. Heterogeneity in mHealth design and purpose also leads to different levels of app usage. For example, apps only being designed as data collection tools instead of comprehensive interventions might not lead to positive changes in health behaviour [136]. Similarly, merely providing health information on a regular basis is proven to be ineffective unless reinforcement and motivation are also provided [89, 137]. As mentioned above, inadequate application of behavioural change theory to guide the design and implementation of mHealth services also leads to unsatisfactory intervention effects [134, 138-140]. In addition, although often being the targeted audience for requirements acquisition at the initial mHealth app design stage, it is a common challenge for patients to fully conceptualise their needs for mHealth services that support them to self-manage chronic conditions [135]. These may lead to the ineffectiveness of the mHealth services [141-145]. Therefore, the last research question is

> *Research Question 4. How to effectively apply the above-mentioned findings to the design of mHealth services to support patient self-manage chronic conditions?*

2.5 The Potential Methods that Can Be Used to Address the Research Gap

2.5.1 Literature Review

A literature review uses systematic methods to identify, select and critically appraise secondary data from existing research studies, and synthesise findings qualitatively or quantitatively to answer a clearly formulated question [45, 146]. Through a new interpretation of existing materials, the literature review can track the progress of knowledge in our research field and help us identify the gaps to be studied. As literature review are widely used to understand the current research status in the field and identify the need for additional research, it is used to address the first research questions, i.e. What are the health outcomes of mHealth services to support patient self-management of chronic conditions and the essential components of mHealth services to achieve these outcomes. To ensure the quality, the review was guided by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses [147], and Mixed Methods Appraisal Tool [148] was used to evaluate the data quality of the included literature.

2.5.2 Survey Research

Interview survey

The interview survey is a staple approach to be used in conducting qualitative research [51]. The first advantage of interviews is that the interviewer can have an in-depth understanding of the details the interviewee provided. The interviewee can describe their specific views on a given topic. Face-to-face interviews are deemed to be the gold standard, or the assumed best mode in comparison with other types of interview such as telephone interview because interviewee's social prompts (such as facial expressions, body language) can provide the interviewer with a lot of additional information, showing emotions or originally hidden interconnections, which is difficult to capture in other types of study. Second, researchers can not only understand specific events but also gain insights into people's inner experiences, especially how people perceive and how they understand their perceptions [50, 149]. In this way, researchers can clearly understand the reasons for the event instead of the event itself or their reaction to the event. Therefore, this method is suitable for addressing Question 2, i.e., what is the mechanism for mHealth services to support patient self-management of chronic conditions?

However, before conducting the field investigation, the inherent shortcomings and risks of the interview method were also analysed, and a series of pre-plans was formulated to reduce the bias as much as possible. First, to ensure the readability of the interview design, a pilot test was conducted to validate the content of the interview guide and modified the problems that occurred before the formal interviews. Second, considering the difficulty of recruiting patients to agree upon the right time and place with the researcher, and in many cases, the temporary cancellation of the pre-set interview from the interviewee [149], this study adopted a convenient sampling method to ensure that a certain number of interviews were completed within a certain period of time. Third, in the thematic analysis after the interview, coding is a very time-consuming approach, and objectivity cannot be ensured if it was done by only one researcher [149]. Therefore, a way of one person to code, one person to validate, and the third person to arbitrate was adopted to ensure scientific rigour [53].

Questionnaire survey

A questionnaire survey is an approach that collects statistical information about the attributes, attitudes or behaviours of the population through a structured series of questions [150]. It is only applicable to gather the types of information needed to answer research questions and those from whom researchers hope to obtain information and are often designed for statistical analysis of the responses. Compared with other types of surveys such as interviews and focus group discussions, the questionnaire survey takes advantages due to its low cost and standardisation, less time-consuming and laborious, and more convenient data compilation and process [151]. To ensure scientific rigour, a literature review was used to find similar questions in the previous questionnaire [110]. Content validation and item sorting were also conducted on the designed questionnaire [109]. The results of the questionnaire were analysed using the partial least square structural equation modelling (PLS-SEM) by the software program SmartPLS (Version 3.0) [152, 153]. The statistical results were reported in accordance with the latest reporting requirements suggested by Hair et al. [152].

2.5.3 mHealth Service Prototype Design Research

Design research originally refers to the primary research on the design process and has now been expanded to research embedded in the design process, including work related to the design context and research-based design practice [154]. As one of the integral parts of design research, prototyping is the process of building an early sample, model or release of a product created to test a concept or process, which allows designers to quickly test and improve proposed ideas in a timely manner [155]. In practice, regardless of whether the early work preparation is adequate, whether in-depth research and a large amount of information have been collected, the early stages of designing a product or service cannot obtain the necessary conditions to achieve the optimal solution. As designers may be easily limited by the information and knowledge they collected in the early stages of design, which biases the overall project idea. Prototypes can provide patient users with a complete concept of the final result, reveal the biases of related ideas in the design, identify unnecessary elements that are best discarded, simplify the design and development process, and focus on important elements. This not only avoids global changes in the finished layout, it greatly reduces the designer's workload when developing projects, saves costs, and can also discover insights about users, which can be used to improve existing solutions or create new solutions. Therefore, a prototype mHealth service design approach is suitable for testing and improving our proposed framework in practice.

Chapter 3

Mobile Health Services to Support Self-Management of Chronic Conditions - Unhealthy Alcohol Use

Forward

Starting from the description of risk factors for chronic conditions, the previous chapter reviewed the body of literature regarding the current status and challenges of chronic condition management and mHealth services to support patient self-management of chronic conditions. After discovering the research gaps, it proposed possible methods to address these gaps. This chapter focuses on addressing Research Question 1 of the PhD project, i.e., what are the health outcomes of mHealth services to support patient self-management of chronic conditions and the essential components of mHealth services to achieve these outcomes. It undertakes a systematic review in the context of one typical chronic condition, unhealthy alcohol use, in which a conceptual framework of structural components of mHealth services and outcomes are formulated, which contains five structural dimensions of mHealth services to achieve three types of health outcomes in supporting patient self-management of unhealthy alcohol use. The framework provides guidance to the design of mHealth services to support patient self-management of chronic conditions.

This chapter is a reproduction in full of the paper "Mobile health interventions for self-control of unhealthy alcohol use: systematic review" authored by **Ting Song**, Siyu Qian and Ping Yu, and published in *JMIR mHealth and uHealth* 7, no.1 (2019): e10899.

The numbers of figures, tables, sub-headings and appendices have been re-numbered to keep the coherence of this thesis.

Abstract

Background: Unhealthy alcohol use (UAU) is one of the major causes of preventable morbidity, mortality and associated behavioural risks worldwide. Although mobile health (mHealth) services can provide patients with an effective means for self-management of UAU in a timely, ubiquitous, and cost-effective manner, to date, there is a lack of understanding about different health outcomes that can be brought by such services. The core components of these services are also unclear.

Objective: To systematically review and synthesise the research evidence about the efficacy of mHealth services on various health outcomes for patient self-management of UAU and to identify the core components to achieve these outcomes.

Methods: Seven interdisciplinary electronic databases: Scopus, PubMed, PubMed Central, CINAHL Plus with full text, MEDLINE with full text, PsycINFO and PsycARTICLES were systematically searched. Search terms and MeSH headings, "mHealth", "text message", "SMS", "App", "IVR", "self-control", "self-regulation", "alcohol*", "intervention" were used individually or in combination to identify peer-reviewed publications in English from 2008 to 2017. The titles and abstracts, and full-text articles were screened and analysed as per inclusion and exclusion criteria. Data were extracted from the included articles according to the CONSORT-EHEALTH checklist (V.1.6.1) by two authors independently. Data quality was assessed by the Mixed Methods Appraisal Tool. Data synthesis and analyses were conducted following the procedures for qualitative content analysis. Statistical testing was also conducted to test differences among groups of studies.

Results: Nineteen studies were included in the review. In twelve studies (63%), mHealth services brought significant positive outcomes in improving patients' health as measured by behavioural (n=11), physiological (n=1), and cognitive indicators (n=1). No significant health outcome was reported in six studies (32%). Surprisingly, a significant negative outcome was reported for the male participants in the intervention arm in one study (5%), but no change was found for the female participants. Five core components reported in the mHealth services for patient self-management of UAU were context, theoretical base, delivery mode, content and implementation procedure. However, sound evidence is yet to be generated about the role of each component for mHealth success. The health outcomes were similar regardless of types of UAU, deployment setting, with or without non-mobile co-intervention and with or without theory.

Conclusions: Most studies reported mHealth services for self-management of UAU appeared to be improving behaviour, especially the ones delivered by SMS and IVR systems. Further studies are needed to provide sound evidence on the effects of mHealth services on improving physiological and cognitive outcomes, as well as to validate their short- and long-term health benefits and contributing factors.

Keywords: systematic review; unhealthy alcohol use; UAU; self-control; mobile health; mHealth; health outcomes; components

3.1 Introduction

Unhealthy alcohol use (UAU) is one of the major causes of preventable morbidity, mortality and related behavioural risks around the world [156, 157]. Approximately 3.3 million deaths, accounting for 5.9% of global deaths, were caused by alcohol-related problems annually [5]. Nearly 81% of adults in Australia consumed alcohol, and UAU contributed to around 70,000 emergency department presentations in 2014 and 2015 [158, 159]. Unhealthy alcohol use may cause allergic reactions, hormonal disturbances and intoxication [160, 161]. Over time, it may cause physical diseases such as alcoholic hepatitis, diabetes, cardiovascular and cerebrovascular diseases [73], or psychological problems like depression, obsession, mania and suicide [162, 163]. Once the brain and neurons were anesthetised, UAU can cause a person to lose self-control [32], leading to social problems such as conflicts, unprepared sexual activities, drunk driving and violence [164, 165]. Therefore, UAU is not only a profound public health challenge but also a social concern.

As an umbrella term, UAU covers various degrees of adverse effects of alcohol use on people's well-being [166]. According to the severity, there are two major types of UAU: risky drinking and alcohol use disorder (AUD) [166, 167].

Risky drinking refers to alcohol use that leads to the risk of adverse health consequences [167]. It can be measured by the number of standard drinks (SDs) consumed. An SD is defined by the amount of pure alcohol contained in a drink, and it varies among countries [165, 167, 168]. For example, in Australia, an SD contains 10 grams of pure alcohol; in the UK and Iceland, it contains only 8 grams; while in Austria, it is 20 grams [168]. It is deemed risky drinking if total weekly alcohol consumption is greater than or equal to 15 SDs for men and 13 for women in the US, or over 14 SDs for men and 9 for women in Sweden [32, 169, 170]. On a single occasion, if alcohol consumption is more than 5 SDs for men and 4 for women, it is also seen as risky drinking, risky single-occasion drinking (RSOD) or heavy episodic drinking (HED) [170-172]. Risky drinking can also be measured by scales such as Alcohol Use Disorders Identification Test (AUDIT), AUDIT for Consumption (AUDIT-C) and Fast Alcohol Screening Test (FAST) by scoring over 8 for men and 6 for women in the AUDIT [91, 169, 172], 4 for men and 3 for women in the AUDIT-C [173, 174] or scoring three or higher in the FAST [175].

The other major UAU type is AUD. It is a chronically recurrent brain impairment in which compulsive and maladaptive alcohol use results in behaviour dysregulation and negative mood once alcohol is ceased [167, 176]. Alcohol abuse and alcohol dependence are two representatives for moderate and severe degrees of AUD, respectively [167, 176, 177]. Patients with either of them suffer from adverse consequences. Alcohol abuse, i.e. unrestrained alcohol use, can make patients fail to meet their major obligations and cause or exacerbate health and social problems [167, 178]. More seriously, alcohol dependence, i.e., a constant and strong desire for alcohol causing loss of self-control and consideration of health, may result in physical or mental health problems once a large amount of alcohol is consumed over a long period [93, 179]. Two types of common measurement for AUD are SD and HED. If SD is no less than 21 for men and 14 for women or HED is no less than two within 30 days, it is regarded as AUD [92].

Mobile health (mHealth) refers to the use of mobile devices, such as mobile phones, personal digital assistants or other wireless devices, to deliver medical or public health services [20]. Due to limited human resources available for delivering continuous healthcare services for community-dwelling patients suffering from chronic conditions, mHealth services are increasingly considered by the decision-makers as a potential alternative solution in providing the same quality but low-cost services to address the challenge [180]. Likewise, there has been a growing interest in using mobile phones to deliver public health intervention services to support patient self-management of UAU [169, 172, 181, 182].

To date, mobile health is mainly delivered solely or in a combination of three channels: short message services (SMS) text messaging, apps and interactive voice response (IVR). SMS text messaging has been used to guide patients to change alcohol use behaviour, for example, to reduce alcohol intake, and thus to enable self-control of UAU [32, 171, 182]. App has been used to monitor patients' alcohol use and provide visual feedback about drinking behaviour based on a statistical analysis of input data. By raising self-awareness, it has ignited patients' self-regulation to reduce alcohol use [90]. Interactive voice response has been used to generate audial interactions and provide automatic answers to patient queries on UAU [95, 172]. Therefore, evidence suggests that these three delivery channels can all provide effective and efficient intervention for patient self-management of UAU.

Recent reviews on health intervention services for self-management of UAU have either focused on using electronic health (eHealth) services [183, 184] or on specific areas of mHealth services [185-187]. Two reviews on eHealth services recommend that real-time, personalised feedback is beneficial [183, 184]. Keoleian et al. have specifically reviewed SMS-enabled services for UAU and find them promising [185]. Two later reviews suggest that services delivered via the Internet, SMS and apps have high fidelity, anonymity, accessibility and efficacy for reducing alcohol use [186, 187]. However, none of these studies has found sound evidence about clear health outcomes of these mHealth services, nor have they identified the components of these services. This knowledge gap has hindered the effective adoption and use of mobile technology in public health prevention and intervention service programs against UAU. Therefore, this review aims to understand and synthesise the research evidence about the health outcomes of mHealth services for patient self-management of UAU and to identify their core components.

3.2 Methods

A mixed-method systematic review was conducted. Literature search and screening followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) [147]. Data extraction was guided by the CONSORT-EHEALTH checklist (V.1.6.1) [188]. The methodological quality of the studies was assessed by the Mixed Method Appraisal Tool (MMAT) [148]. Data synthesis and analysis followed the principle of realist synthesis [189] and qualitative content analysis [190]. Statistical testing was also conducted to test differences among groups of studies.

3.2.1 Literature Search and Screening

The literature search was performed from December 2016 to March 2017 in four interdisciplinary electronic databases: Scopus, PubMed (PMC), CINAHL Plus with full text and MEDLINE with full text. The following terms and MeSH headings were used individually or in combination to identify the relevant publications: "mHealth", "text message", "self-control", "self-regulation", "alcohol*". To ensure adequate coverage, a manual search was also conducted to identify papers cited by the relevant publications and reviews. The search was restricted to journal articles (1) published in English, (2) from 2007 to 2017, (3) of which abstracts were available, and which were (4) peer-reviewed. In addition, the following criteria were used in the selection of papers.

Inclusion criteria

Included were papers in which (1) the research focused on supporting patient self-control of UAU, including comorbidities like HIV and depression, or unhealthy behaviour such as smoking; (2) health intervention service was delivered through mobile technologies; (3) the data were collected from empirical studies.

Exclusion criteria

Excluded were papers which (1) reported passive therapy rather than active patient participation in daily self-control of UAU; (2) did not report any alcohol-related outcome; (3) did not have a comparison group; or (4) were review articles, study protocols, conceptual papers, editorials, government reports or guidelines in the topic area.

3.2.2 Data Extraction

Data were extracted using a combination of an Endnote X8 and an Excel spreadsheet by two authors independently. These included name(s) of the author(s), year of publication, country of origin, population type, study setting, type of UAU, study type, eligibility, sample size, study arms and grouping, non-mobile co-intervention, mHealth services theory, delivery mode, mHealth service content, implementation procedure, measurement and outcomes.

3.2.3 Quality Assessment of the Studies

Quantitative randomised controlled studies were assessed using the criteria in Section 2 of MMAT, in terms of randomisation or sequence generation, allocation concealment, outcome data and attrition. Quantitative non-randomised studies were assessed using the criteria in Section 3 of MMAT, in terms of participants' recruitment, health outcome measurement, grouping situation and controlled conditions, and completeness of collected data. Responses to each criterion were "yes", "no", or "can't tell".

3.2.4 Data Synthesis and Analyses

Data were synthesised and analysed using an inductive method. All data collected were reviewed and identified similar notions and tagged them with the same code. Then the codes were grouped with similar meaning into an overarching concept. Concepts with similar meaning were further grouped into a category that addresses our research question. The coding and data management was iteratively developed through constant comparison of the similarities and differences among codes. Chi-square testing was conducted to assess whether there were significant differences in the health outcomes among groups of studies with different conditions.

3.3 Results

3.3.1 Search Outcome

The primary search yielded 349 publications. Eight papers from the reference list and other reviews were added. After removing duplicates, 303 articles remained. Their titles and/or abstracts were manually screened against the inclusion and exclusion criteria. This led to 106 candidate papers. Eighty-six of them were excluded after further scrutinizing the full paper. Finally, 20 papers were included (see Figure 3-1), of which 55% (11/20) met all four MMAT criteria [32, 92, 94, 95, 171, 172, 182, 191-194] and 35% (7/20) met three criteria [90, 93, 169, 170, 173-175], indicating high methodological quality in 90% of these studies.

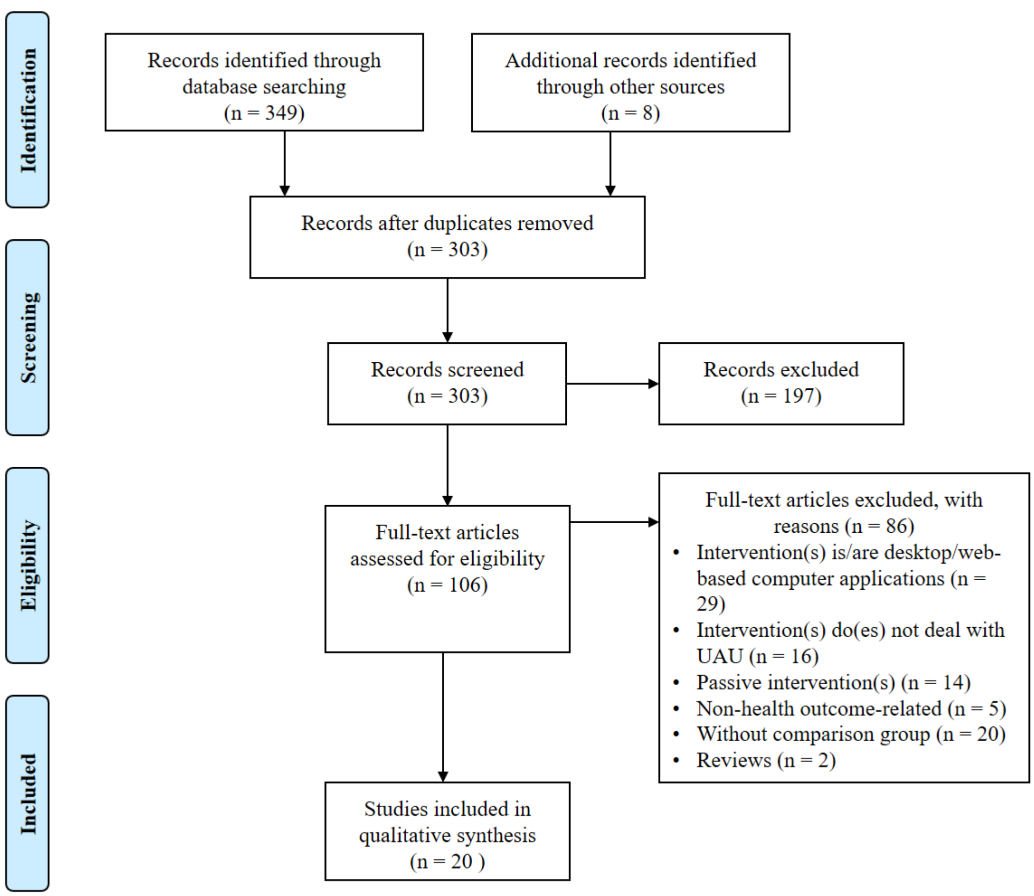

Figure 3-1 Literature search and screening process

3.3.2 Characteristics of Studies

Twenty eligible studies were conducted in six developed countries during 2012-2017 (Table 1) [32, 90-95, 169-175, 182, 191-195]. Eight studies (40%) were published in 2014, accounting for the largest proportion [90, 91, 93, 94, 169, 170, 174, 175]. Eleven studies (55%) were conducted in the US [32, 90-95, 173, 174, 182, 192], eight in Europe [169-172, 175, 191, 193, 194] and only one in New Zealand [195].

Eighteen studies were randomised controlled trials (RCTs) [32, 90, 91, 94, 95, 169-175, 182, 191-195]. One study was a quasi-experiment [92]. Mason et al. conducted a trial and compared its results with those of a relevant group in a previous RCT conducted [93].

The sample size varied from 18 to 1,768 participants. All studies except one [170] reported eligibility criteria. These included the participants: (1) passed a certain threshold for alcohol use or already in treatment [32, 90-95, 169, 172-175, 182, 191-194]; (2) had a frequently-used mobile phone [32, 90, 92, 169, 171, 175, 182, 191-194]; (3) had the required level of cognitive and language capability [32, 95, 173, 191, 193, 194]; and (4) passed a certain age threshold [32, 90, 92, 93, 175, 182, 192-195].

Study arms ranged from two to six. Thirteen studies (65%) were two-arm trials with an intervention arm and a control arm [90-93, 170, 171, 175, 182, 191-195]. The control-arm participants received (1) no mHealth service [90, 91, 171, 191]; (2) non-mobile intervention with the same content through email [170], booklet [92, 175] or e-booklet [93]; (3) non-alcohol-related content through the same mobile devices [182, 193, 194]; (4) only assessment [195], or (5) the same mHealth services as those in the intervention-arm but different rewarding mechanisms for their abstinence [192]. Five studies (25%) had three arms [94, 95, 169, 173, 174]. Besides intervention and control arms, three of them added an assessment-only arm in which the participants only received an assessment for monitoring purpose [94, 173, 174]. Hasin et al. employed an arm in which the participants only received part of the intervention [95]. Gajecki et al. used two parallel intervention arms delivered by two different mobile apps [169]. In the last two studies (10%), Andersson conducted a five-arm RCT in which mHealth service was compared with web-based intervention and non-intervention. Both the mHealth and web-based interventions had two implementation procedures, single and repeated [172]. Muench et al. employed a six-arm design, including one non-intervention arm, one assessment-only arm and four intervention arms containing different contents [32].

We identified five common components of mHealth services for UAU: context, theoretical base, content, delivery mode and implementation procedure; and three types of health outcome: behavioural, physiological and cognitive outcome (see Figure 3-2 and Appendix A).

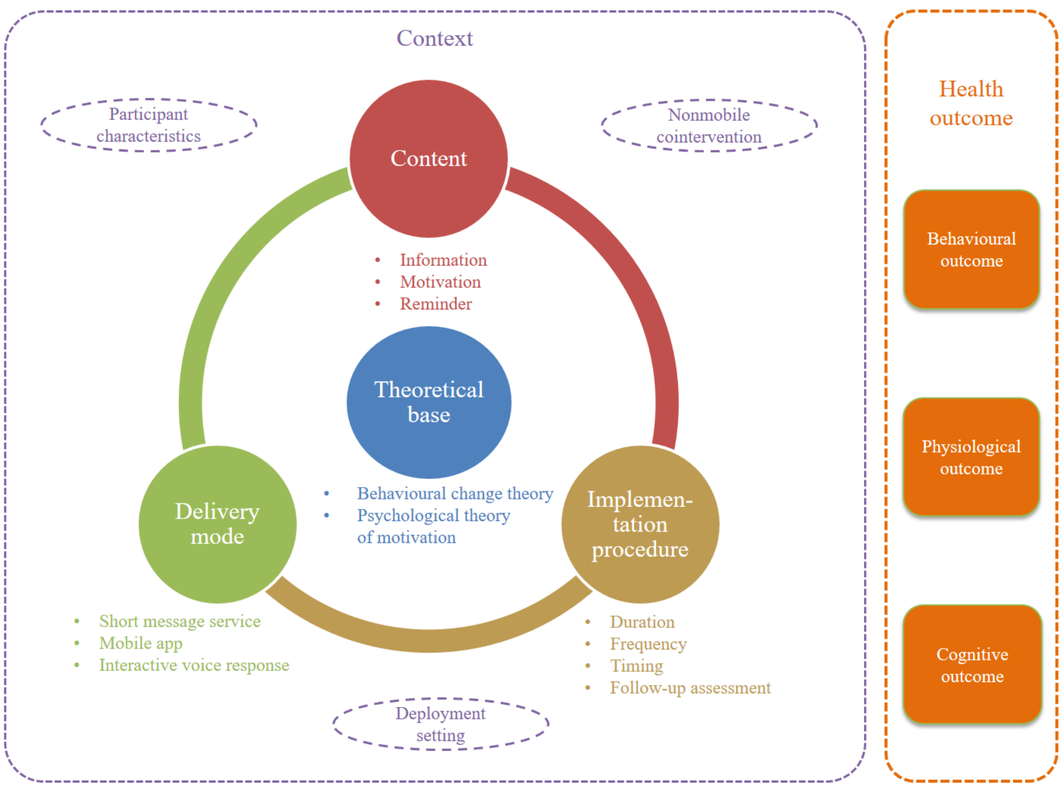

Figure 3-2 Five components of mHealth services for self-management of UAU and the health outcomes achieved

3.3.3 Five Common Components of mHealth Services for Self-management of UAU

Context

There are three types of context: participant characteristics, deployment setting and non-mobile co-intervention that was conducted simultaneously to support the mHealth service. The participants were 18 years and over except Hung et al.'s study [171], which targeted adolescents between 16 and 19 years of age. They were risky drinkers [32, 91, 94, 95, 169-175, 182, 192, 195] or had AUD [90, 92, 93, 169, 191, 193, 194] . They suffered from comorbidity of HIV [93, 95], depression [193, 194] or smoking [94]. The interventions were deployed in clinical settings [90, 93, 95, 173, 174, 191, 193, 194], educational settings [91, 94, 169-172, 182, 195], and community-based settings [32, 92, 175, 192]. The non-mobile co-intervention included human intervention guided by the theory of motivational interviewing (MI) [90-95], web-based intervention [171] and paper-based intervention [32].

Theoretical base

One or more theories were reported to have been used to guide the design and implementation of the mHealth services [32, 90, 92, 94, 169-171, 173, 174, 191, 192, 195]. These theories can be grouped into two types: behavioural change theories and psychological theories of motivation.

Behavioural change theories included Theory of Planned Behaviour [169, 170, 173, 191, 195], Social Cognitive Theory [170, 171, 195], Cognitive-behavioural Treatment [92, 94], Health Belief model [32, 174], Social Learning Theory [32], Behavioural Self-management Techniques [191], Theory of Reasoned Action [174], Health Action Process Approach [171] and Information Motivation Behavioural Model [174]. Psychological theories of motivation included Self-Determination Theory [90, 170, 195], Model of Action Phases [170, 195], Ecological Momentary

Assessment (EMA) [94, 195], Ecological Momentary Intervention (EMI) [195] and Contingency Management [192].

Delivery mode

Three delivery modes were identified: SMS (13/20, 65%) [32, 91, 170, 171, 173-175, 182, 191-195], app (5/20, 25%) [90, 92-94, 169] and IVR (2/20, 10%) [95, 172]. Six apps used in the five studies were LBMI-A (Location-Based Monitoring and Intervention for AUD) [92], BASICS-Mobile (Brief Alcohol and Smoking Intervention for College Students via Mobile) [94], HealthCall-S [93], A-CHESS (Alcohol-Comprehensive Health Enhancement Support System) [90], PartyPlanner [169] and Promillekoll [169]. Three studies described the operating system for these apps to work. One app ran on the Android system [169], one on both Android [93] and iOS, and the third on Blackberry, Android and iOS [94].

Content

Three types of content were designed to support the participants' self-management of UAU. They were information [32, 90-92, 94, 95, 169-175, 182, 193-195], motivation [32, 90-95, 169-175, 182, 191, 193-195] and reminder [32, 171, 173, 174, 192].

Informational content included general and personalised information. The general information facilitated the participants in (1) enriching their knowledge about alcohol-related facts [94, 172, 175, 182], social drinking norms [91, 174], eBAC calculation [171], risks and negative consequences of UAU [32, 171, 172, 174, 175, 182, 195] and benefits of reducing drinking amount according to safety guidelines [32]; (2) acquiring strategies to control alcohol use [91, 92, 94, 169, 171, 173, 174, 182], to handle relapse or cravings [92, 94, 175, 193, 194], to manage emotion [175] and to reduce intoxication [95]; (3) getting referrals such as alcohol counseling services available [92, 171], instant library and web-links to further alcohol-related information provided in video clips, pictures and websites [90, 171] and high-risk drinking locations [92]; and (4) conducting recommended actions for self-management of UAU, such as conducting alcohol-related testing [171], registration of alcohol use [169] or simulating a drinking occasion to set personal goal of eBAC and comparing actual eBAC after drinking against this goal [169].

The personalised information helped the participants in (1) tracking and reporting their drinking facts [32, 90-93, 95, 169, 171-175, 191, 195], eBAC value [169], mood [95], medication adherence [95], wellbeing [95] and reasons for drinking or abstinence [95]; (2) providing the tailored feedback according to their responses [32, 92, 94, 171-174]; (3) recommending them to set intermittent low-risk drinking goals [175], to replace drinking alcohol by alternative activities [92, 94, 172], to celebrate goal attainment [173-175], to self-reflect on challenges of UAU [170], to improve the drinking plan and to reinforce self-management behaviour [172-174] or to return to counselling service [92]; and (4) addressing their problems identified at various stages [32].

Motivational content included (1) encouragement messages for reducing alcohol use [91, 94, 170-175, 182, 193-195], releasing distress [90] and committing to pre-set drinking goals [32, 173, 174, 191] and medical adherence [193, 194]; (2) peer support through sharing experiences with others in the anonymous discussion groups [90]; and (3) contest for designing motivational SMS messages to control UAU [171].

Reminding content included (1) reminding participants to remember and fulfil their promises [171, 173, 174, 192]; (2) warnings of alcohol risks at the personal risky drinking times [32].

Implementation procedure

The duration of the interventions varied, ranging from four days [91], one week [195], two weeks [94], four weeks [93, 170, 172, 192], six weeks [92, 182], seven weeks [169], two months [95], three months [32, 171, 173, 174, 193, 194], six months [175, 191] to eight months [90].

With regard to the message frequency, SMS text messages were sent once [32, 171], twice [170, 173, 174] or four times [182, 195] per week in seven studies and once [91], twice [193, 194] or one to three times [192] per day in four studies. The frequency appeared to reduce when the length of the study increased [175, 191]. Haug et al. sent one message per week in the first eight weeks, then one per fortnight in the remaining 18 weeks [191]. Brendryen et al. sent one message per day for eight weeks, then one per week for four weeks, and finally, one per month in the last two months [175]. The participants in Alessi and Petry's study were given a breathalyser and the corresponding accessories to self-measure BrAC and submit a valid real-time video containing the whole self-measuring process to the organiser via text message one to three times per day at the fixed time interval to prove their abstinence [192]. The intervention-arm participants would be rewarded with more vouchers if their BrAC value was normal. In contrast, the control-arm participants were not rewarded, even though their BrAC value was normal [192].

Apps were used by the participants in real-time, typically to receive a certain recommendation once a pre-set condition was met. For example, Promillekoll could send real-time notification and the corresponding strategies to control alcohol use if a participant's eBAC was over 0.06% [169]. A-CHESS and LBMI-A would send an alarm when a participant was near a high-risk alcohol place to be detected by the embedded global positioning system [90, 92]. Similarly, HealthCall-S would suggest a participant contact with a counsellor for personalised feedback once the occurrence of risky drinking was identified [93].

Andersson divided his intervention arm into two sub-groups, both receiving the same content but through different delivery modes, either delivering a single IVR every day for one week or delivering repeated IVR for four weeks [172]. Hasin et al. requested their intervention-arm participants to spend one to three minutes per day to send back their answers to a series of questions asking their compliance with drinking guidelines on the previous day via a toll-free number [95]. The participants' phone calls were initially answered by the pre-recorded IVR in the first 30 days. After evaluating a participant's IVR data, the consultant reset the person's drinking goal for the next 30 days [95].

All studies conducted baseline assessments. Only one study conducted an assessment during the intervention period to explore the initial outcome [175]. The post-intervention assessments were conducted in all studies at different time points with a different number of repetitive measures. Seventeen studies (85%) only conducted one assessment immediately after the intervention [32, 90, 92-95, 169, 170, 173-175, 182, 191-195]. Six studies conducted the second assessment six weeks [182], one month [93], two months [94], one academic semester [195], three months [173, 193, 194] and four months after the intervention [90]. Two studies conducted the third assessment three months [173] or eight months after the intervention [90]. Instead of immediately measuring the outcomes, in two studies, the measures were conducted only after one [91] or three months [171]. One study measured the outcome four weeks after the intervention for the single IVR intervention-arm and one week after the intervention for the repeated IVR intervention-arm [172].

3.3.4 Health Outcomes

Behavioural outcomes

Behavioural outcomes were measured in 19 studies [32, 90-95, 169, 171-175, 182, 191-195]. Significant positive outcomes were found in 13 of them [32, 90, 92, 95, 171-175, 192-195]. These positive outcomes were measured by one or more indicators. These included the decreased number of SDs [32, 92, 173-175, 195], HDDs [32, 90, 92, 95, 173, 174, 192], RSOD/binge drinking prevalence [171, 173], alcohol-related injury prevalence [173], and increased number of abstinence days [32, 92, 192, 193]; or the increased negative affect score in Alcohol Abstinence

Self Efficacy Scale (AASE) [194] and the decreased score in the Alcohol Addiction Severity Index (ASI), Drinker Inventory of Consequences (DIC) [192] or AUDIT [172].

No significant change was found in five studies [91, 93, 94, 182, 191]. Two studies reported a gender-related behavioural outcome [169]. Contrary to the initial objective of reducing UAU, the male participants in the intervention arm significantly increased drinking frequency, whereas no change was found in the female participants and the control arm in one study [169]. The gender-related difference was also found in the study [195]. After providing intervention-arm participants with one-week SMS text messages, the female participants consumed significantly less alcohol one-week and one-semester later than their female counterparts in the control arm. However, no intervention effect was found for male participants [195].

Physiological outcomes

Physiological outcomes were measured in five studies via eBAC [169, 171, 172, 182] or BrAC [192] and were significantly positive in two of them [172, 192]. Andersson identified a significant peak eBAC reduction for the repeated and the total (single and repeated) IVR group [172]. Alessi and Petry found a significant improvement in the percentage of negative BrAC [192]. No significant change was found in the other three studies [169, 171, 182].

Cognitive outcomes

Cognitive outcomes were measured in three studies [91, 92, 170] and were significantly positive in only one study, in which the participant's readiness to change UAU behaviour in the intervention arm was significantly improved [91]. No significant cognitive change was found in the other two studies [92, 170].

3.3.5 Comparison of the Differences in Health Outcomes among Different Groups of Studies

Studies were classified into two groups according to types of UAU, being risky drinking or AUD; with or without non-mobile co-intervention; theory-based or not; or three groups as per the deployment setting, being clinical, educational or community-based. The Chi-square test did not find any significant differences in health outcomes among these groups. It suggested that the health outcomes were similar regardless of the types of UAU studied, whether there was non-mobile co-intervention, whether the study was theoretical-based or in which setting it was deployed.

3.4 Discussion

3.4.1 Principal Results and Comparison with Prior Work

This study aims to synthesise the research evidence about the health outcomes of mHealth services for patient self-management of UAU and to explore their common components. Twenty papers were systematically reviewed to compare the health outcomes and the five components of these interventions: context, theoretical base, delivery mode, contents and implementation procedure.

Health outcomes

The health outcomes of the mHealth services for UAU that has been measured included behavioural outcome (n=19) [32, 90-95, 169, 171-175, 182, 191-195], physiological outcome (n=5) [169, 171, 172, 182, 192] and cognitive outcome (n=3) [91, 92, 170]. Significantly positive behavioural outcomes were reported in 13 studies. These included a reduction in SDs or HDDs [32, 90, 92, 95, 173-175, 192, 195], reduction in the prevalence of RSOD/binge drinking and alcohol-related injury [171, 173], increased number of abstinence days [32, 92, 192, 193], increased negative affect sub-score in AASE [194], and reduced scores in AUDIT, Alcohol ASI or DIC [172, 192]. A significant physiological outcome was reported in two studies, including improvement in n-BrAC [192] and peak eBAC [172]. Only one study reported the significantly positive cognitive outcome of increased readiness to change UAU [91]. A relatively small sample size [182, 191] and a short follow-up period [94] may cause a lack of significant health outcomes for the mHealth services.

Complementing the traditional interventions such as face-to-face counselling, in which unhealthy alcohol users' access to treatment was provided in a passive manner within a confined time and location, mHealth services open new opportunities for engaging patients in positive self-management with increased flexibility. The effect of control was improved by continuous tracking and monitoring, interactive communication or personalised feedback from healthcare providers anytime, anywhere [196, 197].

Five components of mHealth services for self-management of UAU

We identified three parameters to describe the context for mHealth service: participant characteristics, deployment setting and non-mobile co-intervention. Participants in most reviewed studies were risky drinkers without documented pathological conditions. Kazemi et al. suggest that for this population group, mHealth service might be the most cost-effective UAU management strategy [198]. We did not find much difference in the intervention outcome between the types of participants, being risky drinker or AUD. This result is consistent with the finding of Blow et al. that the health outcome of the intervention is not influenced by the level of severity of alcohol addiction [199]. The gender difference in intervention outcome found in two studies [169, 195] may be explained by the observation of Hirschi and Gottfredson that men have lower self-management than women [200]. Similar to the finding of Platt et al. [201], we did not find any significant relationship between the health outcome and deployment setting.

Although not having any significant impact on health outcomes, co-intervention, such as induction or training to enable a participant to confidently use the apps or IVR [202, 203], is an integral, vital component for a successful mHealth service. This may explain why more cases of non-mobile co-intervention were reported in interventions delivered via apps (3/5, 60%) and IVR (1/2, 50%). Most likely, the participants were more familiar with SMS text messaging than the other two delivery modes; therefore, the co-intervention was less reported in the studies delivered by SMS text messaging (4/13, 31%).

The theoretical base for mHealth services includes behavioural change theory and psychological theory of motivation. Behavioural change theory provides the foundation for the formation of strategies to incrementally change a patient's behaviour of UAU [204]. The psychological theory of motivation is used to develop motivational strategies to control UAU against the psychological craving for alcohol [205]. Although mHealth services based on theory can improve instructional design and the effect of self-management of UAU [59], no significant difference in health outcomes was found in this review for the studies based on theory and those otherwise, which is in accordance with the finding of Garnett et al. [206]. There may be two reasons to explain this phenomenon. First, from what was described in the methods, it appears that theory was implicitly applied to the mHealth services even though a study might not make a claim to be theory-based. For example, Bock et al. did not report the use of any theory; however, one of the text messages in their intervention, "always have an exit plan", indicated the unconscious application of the Theory of Planned Behaviour [182]. Second, it takes time to bring intangible health outcomes for participant self-management of UAU [193, 194]. As the length of the reviewed studies was not long enough, ranging from four days to eight months, it is no surprise that there were no obvious improvement intangible health outcomes in many studies.

Mobile health interventions are enabled by three types of technologies: SMS text messaging, mobile phone-based apps and IVR. Almost all SMS- or IVR-enabled interventions are effective in reducing alcohol use or increasing readiness to change except the mobile apps [93, 94, 169]. This may be because the former two types of interventions were delivered proactively, on a regular basis, always accessible to the participants regardless of their intention. In contrast, the participants' access to the app-based interventions relied on their self-action of opening the apps, which may not always happen.

The content included information, motivation and reminder. Informational content provided the participants with essential knowledge and skill to build their capacity to change their belief and

UAU behaviour. It also provided necessary feedback to enable self-awareness of UAU status, thus could execute self-regulation of UAU. Motivational content provided continuous encouragement and peer-support through experience sharing to raise the participants' morale in changing UAU behaviour. Reminding content overcame provided constant recall to ensure the participants to stay on track in self-management of UAU. The delivery of these three types of content is in line with the model of human practical reasoning developed by Michael Bratman [207].

The implementation procedure was unpacked into intervention duration, frequency, and practical execution strategies, which had influenced outcomes. Longer duration [90, 175], more frequent intervention [193, 194] and certain techniques such as tangible incentives [192], and assessment during the intervention [175] would facilitate the achievement of positive outcomes.

With the same content and implementation procedure, Andersson et al. found differences in health outcomes measured by peak eBAC and AUDIT scores with different delivery modes, being IVR or the Web [172]. Likewise, with the same delivery mode and implementation procedure but different content, Muench et al. also found differences in health outcomes measured by numbers of SDs, HDDs and days abstinence. The content that highlighted the negative consequences of UAU were significantly more likely to bring in positive health outcomes than the content that emphasised the benefits of UAU abstinence [32]. Furthermore, with the same content and delivery mode, Hung et al. found that the health outcomes as measured by RSOD prevalence were significantly different with different intervals of the intervention [171].

Although the first generation of the iPhone was released in June 2007, marking the debut of smartphone technology [208], no eligible studies were found before 2012. It appears that using mobile phones to deliver mHealth services for UAU was gaining the spotlight in 2012.

To date, the evidence to support the effectiveness of mHealth services for patient self-management of UAU is modest at best [40-42]. Despite the availability of new apps and their commercial use in this area, this review suggests that research is lagging considerably behind the practice on the effectiveness of these apps in supporting vulnerable patients to self-management of their UAU. This calls for further robust, well-designed studies on how to effectively implement and measure the health outcomes of mHealth to support patient self-management of UAU.

3.4.2 Limitations

The first limitation of this study was that the coverage of the studies might not be exhaustive due to our search was confined to the four databases. However, the comprehensiveness of these databases can ensure the representativeness of the trend suggested by this study. The heterogeneity of participant characteristics, intervention and health outcome measures makes it difficult to compare the findings rigorously among the studies. A lack of homogenous, quantitative measures in the original studies also deemed it impossible to conduct a more rigorous meta-analysis. As only peer-refereed journal articles were included to ensure the rigour of this study, there could be a potential risk of reporting bias towards positive findings.

3.5 Conclusions

This systematic review synthesised the research evidence about the health outcomes of mHealth services for patient self-management of UAU. We analysed the five components of the mHealth services, namely context, theoretical base, delivery mode, content and implementation procedure. In comparison with the traditional interventions, mHealth services are advantageous in helping unhealthy alcohol users to proactively engage in self-management of their UAU behaviour. Sound evidence is yet to be sought about the effects of these interventions in improving physiological and cognitive outcomes. More robust trials are needed to validate the short- and long-term health benefits and the contributing factors in using mHealth services for patient self-management of UAU.

Summary

This chapter contributes to understanding the structure and outcome of mHealth services from the perspective of Donabedian's healthcare quality evaluation model [41], thus addresses Research Question 1. It systematically reviews 20 clinical trials of mHealth services to support patient self-management of unhealthy alcohol use [32, 90-95, 169-175, 182, 191-195] and extracts a conceptual framework for mHealth services. This framework includes five essential structural components – context, theory, content, delivery mode, and implementation procedure. It is aimed to achieve three types of health outcomes – physiological, behavioural, and cognitive outcomes. The framework can be applied to patient self-management of other chronic conditions where the management mechanisms remain the same, i.e., extrinsic guidance from the qualified healthcare providers, and intrinsic factors including self-awareness, knowledge and active management behaviour [8, 15, 84]. Compared with traditional face-to-face interventions, mHealth services are advantageous in helping patients proactively engage in self-management behaviour with a reduced demand for human touch, benefiting from automation of certain functions and electronic communication [196, 197]. The literature study suggests that sound evidence is yet to be sought about the effects of mHealth services in improving physiological and cognitive outcomes of chronic condition management.

Chapter 4

The Use of Theory in mHealth Services to Support Patient Self-Management of Chronic Conditions: Hypertension

Forward

The previous chapter proposed a conceptual framework that included five components and three types of health outcomes of mHealth services in supporting patients' self-management of unhealthy alcohol use. It used the framework to evaluate the intervention process and the effects of such services reported in the literature. One of the significant findings is that although being considered to be a very critical component, the theory was rarely used to guide the design, application and evaluation of mHealth services to support patient self-management of chronic conditions. This is also considered by many scholars to be one of the reasons for the poor effectiveness of mHealth services. To address this research gap, this chapter provides a rapid review of the use of theory in mHealth services to support patient self-management of chronic conditions. The research is useful for improving the design, implementing and evaluating similar services in future.

This chapter is a reproduction in full of the paper "The use of theory in mobile health interventions for patient self-management of chronic diseases" authored by **Ting Song**, Siyu Qian, Tingru Cui and Ping Yu, and published in *Studies in Health Technology and Informatics* 264 (2019): p.1982.

The numbers of figures, tables, sub-headings and appendices have been re-numbered to keep the coherence of this thesis.

Abstract

Background: Mobile health services provide healthcare organisations with a unique opportunity to support patient self-management of chronic conditions. The effectiveness of these services can be improved if the theory is used to guide the design, implementation and evaluation of these services.

Aim: This study aims to investigate the use of theory in mobile health services to support patient self-management of chronic conditions in the hypertension management context.

Methods: A mix-method literature review was conducted. Literature was searched and screened in June 2018 across seven electronic databases: Scopus, PubMed, PMC, CINAHL Plus with full text, MEDLINE with full text, PsycARTICLE, and PsycINFO, following the guideline of Preferred Reporting Items for Systematic Reviews and Meta-Analyses. Terms and MeSH headings such as "mHealth", "self-management", and "hypertension" were used individually or in combination to identify relevant peer-reviewed studies published in English from 2009 to 2018. Data were extracted using Endnote and Excel spreadsheet and were synthesised and analysed using an inductive method. Theory Coding Scheme was also applied to evaluate the extent to which the theories were applied in each study.

Results: Six theories were identified: Health Belief Model, Social Cognitive Theory, Self-determination Theory, Theory of Planned Behaviour, Transtheoretical Model, and Technology Acceptance Model. Regarding the extent to which these theories were reported, most studies only mentioned the use of theory. Several studies described the relevant theoretical constructs. Only a few studies used theory to select recipients, tailor interventions, measure constructs, or test mediation effects. No study reported refining theory.

Conclusion: Mobile health services provide a unique opportunity to develop and refine theories, but there is a lack of reports on such a process in their application to self-management of chronic conditions. Therefore, more attention must be paid to the careful selection, application and reporting of the use of theory to accurately evaluate the value of the theory to the outcomes of mobile health. Our findings are useful for improving the design of mobile health services that support patient self-management of hypertension.

Keywords: mHealth, theory, chronic disease management

4.1 Introduction

Hypertension, or known as high blood pressure, can lead to stroke, heart failure and chronic renal diseases [209, 210]. It is one of the leading causes of global mortality and disability. In 2015, around 1.13 billion people had hypertension worldwide, accounting for 13% of the global death and 10% of total healthcare cost [64, 211, 212]. The efficacy and affordability of healthcare have become a major health and social concern. To ensure the sustainability of the healthcare system, there is a pressing need for innovative methods, tools and processes to overcome this burden and deliver high-quality healthcare services.

According to the latest guidelines, two major types of interventions are effective in reducing blood pressure (BP) to the target and controlling other risk factors: medication treatment and lifestyle intervention [213]. Therefore, to a large extent, hypertension control is about ensuring and maintaining medication adherence and a healthy lifestyle, which requires a more preventative and long-term care plan and implementation.

With the penetration of the Internet and mobile technologies into all walks of life, we are living at the right time for using our mobile devices at hand to support our health and wellbeing. This is because mobile devices, such as smartphones, have provided us with a unique opportunity for monitoring our BP anytime, anywhere to prevent or manage hypertension. Mobile health (mHealth) refers to the use of mobile devices, such as mobile phones or other wireless devices, to deliver medical or public health services [20]. As there is a lack of medical resources for healthcare organisations to deliver continuous healthcare services for community patients who suffer from chronic conditions, mHealth services are increasingly recognised by the decision-makers and patients alike as a potential alternative solution in providing good quality but low-cost services to address the challenge of chronic condition management such as hypertension control [180].

In the comparison of non-theory-based services, theory-based mHealth services have been found to be more effective in changing health behaviour in prior studies [214, 215]. Song et al. developed a conceptual framework of using mHealth services for self-control of unhealthy alcohol use [46]. One of the core components in their framework is theory. Theories were used to design and implement patient self-control of unhealthy alcohol use, which led to the enrichment of the evidence base and improvement of the effectiveness of these healthcare services. Despite the mounting challenge of using mHealth services to support hypertension [180, 216] and the numerous successful cases to date [26-33], to our knowledge, no study has reported how theory is used that support these services. In a recent review, Davis also suggested that it was vital to investigate how to operationalise theories to guide the health behavioural change effort as they were not clearly understood [217]. Therefore, this study aims to investigate the use of theory in mHealth services that support patient self-management of hypertension. It focuses on addressing the following two questions: 1. What theories were used to guide the mHealth services that support patient self-management of hypertension? How were these theories used? and What were the effects of the services? 2. To what extend these theories were reported?

4.2 Methods

A mixed-method review was conducted. Literature was searched and screened in June 2018 across seven electronic databases: Scopus, PubMed, PMC, CINAHL Plus with full text, MEDLINE with full text, PsycARTICLE, and PsycINFO, following the guideline of Preferred Reporting Items for Systematic Reviews and Meta-Analyses [147]. Terms and MeSH headings such as "mHealth", "self-management", and "hypertension" were used individually or in combination to identify relevant peer-reviewed studies published in English from 2009 to 2018. A manual search was also conducted to identify papers cited by the relevant publications and reviews to ensure adequate coverage. In addition, the following criteria were used in the selection of papers. Inclusion criteria were empirical studies reported (1) using mobile technologies to support self-management of hypertension; (2) at least one theory; and (3) hypertension-related outcomes. Exclusion criteria were studies (1) in which the theory has nothing to do with the intervention (3) were reviews, study protocols, or guidelines in the topic area.

Data were extracted using Endnote and Excel spreadsheet and were synthesised and analysed using an inductive method. Theory Coding Scheme (TCS) developed by Michie and Prestwich was also applied to evaluate the extent to which the theories were applied in each study [215]. As reported use of theory was an inclusion criterion for our selection of studies, all studies selected satisfied the measurement item "theory/model of behaviour mentioned" and thus did not need to be further assessed by this. Another two items, "quality of measures" and "randomisation of participants to condition" were seen as irrelevant to the purpose of this review and were also excluded. Therefore, the extent of theory application in each study was measured in two steps. First, we used the 21-item scheme to evaluate each study. If a study conforms to the statement of a measurement item, 'yes' was recorded, and the study was scored 1, otherwise 'no' was recorded, and the study was scored 0. Second, These items were further grouped into six categories of the TCS (see Table 4-1). The items in these categories were 2, 7, 2, 2, 9, 2, respectively. In each category, every item was allocated one score. Therefore, the total scores of each category were 2, 7, 2, 2, 9, 2, respectively. Afterwards, we calculated the mean score and the proportion of the record "yes" to evaluate the extent to which these theories were reported.

4.3 Results

A total of 210 papers were found from the combined database searches. Four papers retrieved from other sources were added. Of these, 86 papers were removed as duplicates, and 128 remained for the title and abstract screen. After screening, 50 papers were selected for the full-text screen. Finally, ten papers were eligible for inclusion in the review (see Figure 4-1).

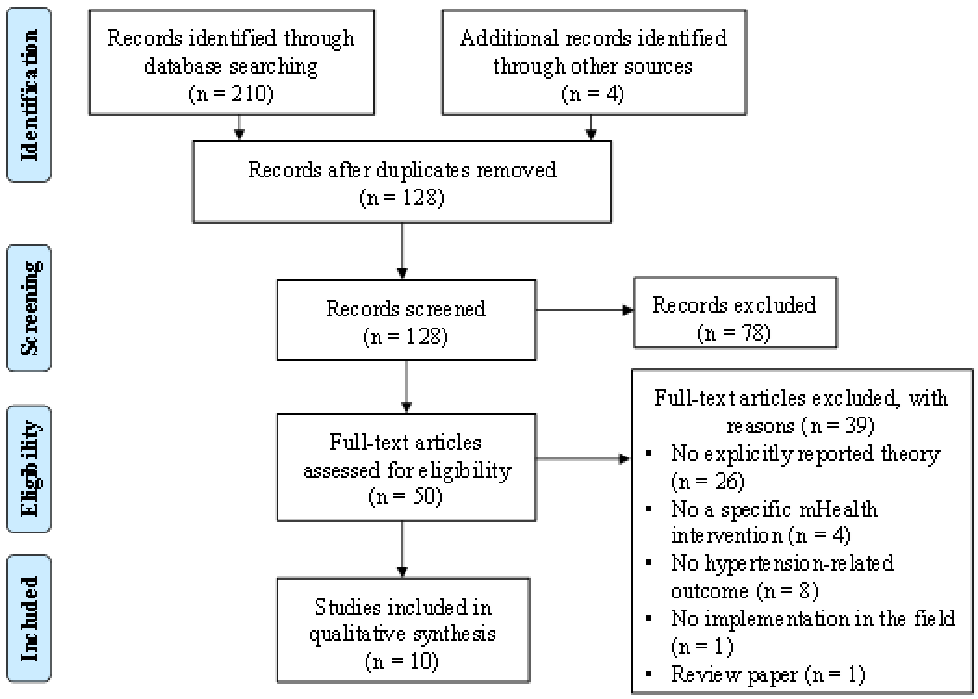

Figure 4-1 Literature search and screening process

The ten included studies were conducted in five countries from 2013 to 2018. None of the studies published before 2013 met our inclusion criteria. Half of the studies (5/10, 50%) took place in the United States, two in South America, two in China, and one in South Africa.

4.3.1 The Theories Commonly Used to Guide mHealth Services that Support Patient Self-Management of Hypertension

Six commonly used theories to guide mHealth services for patient self-management of hypertension are the Health Belief Model (HBM), Social Cognitive Theory (SCT), Self-determination Theory (SDT), Theory of Planned Behaviour (TPB), Transtheoretical Model (TM) and Technology Acceptance Model (TAM). Related constructs or processes to which these theories applied are mapping to the design, implementation and evaluation of the mHealth services (see Figure 4-2).

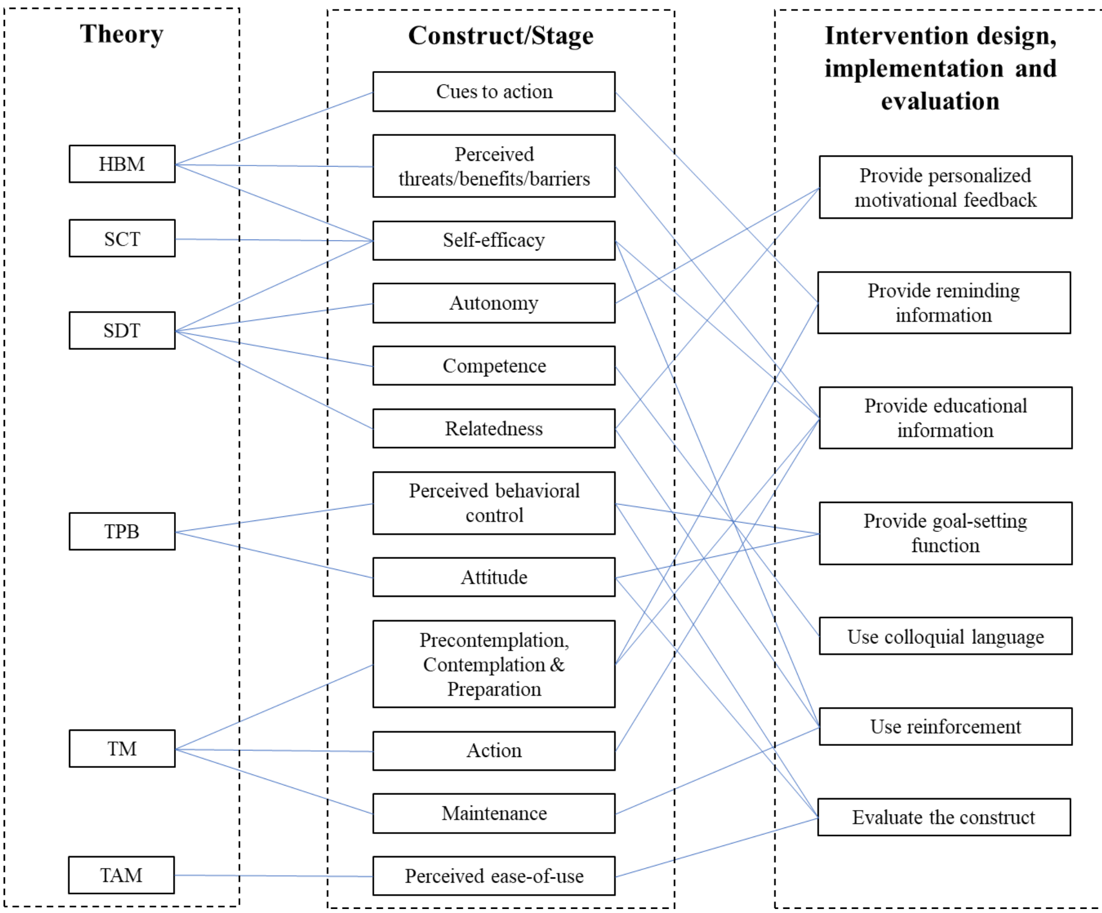

Figure 4-2 The relations among the six theories, their constructs or processes, and the corresponding mHealth services

Health belief model

Health Belief Model (HBM) was reported in three studies either to guide the design [218-220] or to evaluate the effect of the mHealth services [219]. The HBM is a psychological model that explains and predicts preventive health behaviour [221]. It suggests that a person's health behaviour is determined by six key factors: perceived severity of certain diseases, perceived susceptibility, perceived benefit, perceived barriers, self-efficacy, and cues to action.

The purpose of applying the HBM was to increase the behavioural change through continuous reminder [218, 219]. Grounded in the HBM, the reminder, serving as "cues to action", was used to prepare a patient for change and to stimulate his/her corresponding behaviours. Wan et al. conducted a three-month, two-arm RCT to investigate the effect of a reminder system on health behaviours and BP control in 174 hypertensive stroke patients after discharge from hospitals. The patients in the intervention group (IG) were provided with weekly automated (short message service) SMS reminders about medication adherence, healthy lifestyle, clinic visits and precautions against weather changes [218]. This led to the significant improvement in health behaviours, including physical activity, nutrition, low-salt diet, and medication adherence, as well as health outcome measured by the decreased BP level and the controlled BP rate. However, smoking and alcohol use behaviours remained no change. Similarly, Buis et al. conducted two RCTs with 58 primary care and 65 emergency department hypertensive patients to determine the effectiveness of automated text messaging on improving their medication adherence [219]. The patients in the IG received automated daily reminders about the medication intake. The patients in the control groups (CG) received usual care. At the one-month follow-up assessment, the patients in the IG achieved significantly better medication adherence than those in the CG.

The HBM was also implemented in patient education to improve their belief in health behaviour for BP control in a mHealth service [218-220]. Lv et al. provided patients with two smartphone apps. One was used to collect self-monitoring BP readings, and the other was used to visually display the statistical results of these readings [220]. Likewise, Wan et al. assessed patients' level of health belief and informed them about their health conditions and risks related to their self-reported behaviours [218]. The theory-based education enriched patients' health knowledge, increased their perceived severity and susceptibility of hypertension threat, improved their perceived benefits of health behaviours, and reduced their perceived barriers to action for behavioural changes. These led to an improvement in health motivation and self-efficacy, facilitating healthy behaviours.

Buis et al. not only sent two weekly educational messages to their patients in the IG about the hypertension management recommendations but also measured patients' self-efficacy in medication adherence using a 21-item scale [219]. However, no significant improvement in medication adherence and self-efficacy were found.

Social cognitive theory

Social cognitive theory (SCT) was applied in three studies to guide the design of content for mHealth services [220, 222, 223]. The SCT believes that people learn by observing others [224]. It suggests that human behaviour is influenced by the interaction of the following three determinants: personal (self-efficacy about the behaviour), behavioural (positive reward for performing certain behaviour) and environmental determinants (context promoting a behaviour) [225].

The purposes of using the SCT were to increase patient knowledge about risk factors for hypertension so as to improve self-efficacy in behavioural changes to improve medication adherence and healthy lifestyle [220, 222, 223]. Two studies provided their patients with educational information either through SMS text messaging [222] or mobile app [220]. In the IG, Varleta et al. sent 15 different educational SMS text messages to the patients every two weeks to improve patient medication adherence [222]. After six months, medication adherence in the non-SMS CG was significantly decreased but was significantly increased in the SMS IG, suggesting the patients had overcome the main barriers to medication adherence. Similarly, Lv et al. provided the patients with a smartphone app with tailored texts and videos for an educational purpose [220].

After using the app for six months, the patients' hypertension knowledge was improved significantly.

Hacking et al. also delivered 90 SMS-based educational messages about hypertension and suggestions about a healthy lifestyle to the patients in the IG. The patients in the CG only received standard care [223]. After 17 weeks' intervention, although no significant difference was found in terms of overall health knowledge between the two groups, the patient's self-efficacy in the IG was significantly higher than their pairs in the CG. The following focus group interview has reaffirmed that the SMS text messaging did not act as a new source of information but a motivation for change. The patients felt that the intervention was quite useful as they were allowed to continuously review the knowledge to increase their self-efficacy accordingly, at their own pace and in a relatively low-stress environment.

Self-determination theory

Self-determination Theory (SDT) was reported in two studies [120, 225]. The SDT asserts that a person makes a free choice of behaviour based on a full understanding of his/her inherent psychological needs and the environmental circumstances [226]. If satisfied, three innate needs to drive the self-motivated and self-determined behaviour: autonomy, competence and relatedness.

Davidson et al. developed an SDT-guided intervention for changing a patient's health behaviours [225]. First, they provided their patients with personalised motivational feedback according to the person's value, belief, and short and long-term life goals. This promoted the patient's autonomy in behaviour rather than feeling being controlled or forced. Second, they also provided the patients with information in colloquial and readable language to foster competence. This made it much easier for a patient to follow the clinicians' guidance on medication intake and BP monitoring. Third, in order to engage family and friends, who played essential roles in a patient's health-related behaviours, they used patient-specific social reinforcement and motivational messages to increase the degree of their social relatedness. The above strategies led to increased engagement of patients in the intervention.

McGillicuddy et al. also believe that SDT can increase a patient's self-efficacy and intrinsic motivation for long-term medication adherence and BP monitoring [120]. They used the idea of patient and provider-centred design to develop a smartphone-based intervention. The intervention was tested in 20 hypertensive kidney transplant recipients for three months. The IG showed a significant improvement in medication adherence as well as BP monitoring. Therefore, the strategy was successful in increasing the degree of the patient's autonomous management of hypertension.

Theory of planned behaviour

Two studies reported the application of Theory of Planned Behaviour (TPB), a theory that links a person's beliefs with behaviours [220, 227]. The TPB suggests that a person's attitude, subjective norm and perceived behavioural control co-shape his/her intention, affecting the behaviour of the person [228]. Lv et al. used this theory to guide the functional design of the mHealth service [220]. For example, they proposed the goal-setting function to invoke a positive attitude and commitment towards a healthy lifestyle. The intervention included two apps to transmit and display the status of a patient's personalised action plan, treatment goals, and self-monitoring of BP readings; and also a web-based messaging system to provide patient-specific educational text messages and videos, as well as interactive communication between patients and healthcare providers. At the end of six months, the intervention significantly controlled patients' office-measured and home-monitored BP and changed their behaviours towards the healthy lifestyle.

Instead of guiding the design of the mHealth service, Sun et al. used the TPB to develop the measurements of the intervention [227]. Four parameters were measured in terms of a patient's behaviour: behavioural intention, attitude toward behavioural change, subjective norms, and perceived behavioural control. After using the intervention for six weeks by 20 Chinese hypertension patients, the patients modified their previous sub-optimal health beliefs towards believing in a healthy lifestyle equipped with the knowledge acquired from their own experiences.

Transtheoretical model

Transtheoretical Model (TTM), also known as Stages of Change Model, was used in two studies [223, 229]. It is an integrative theory that evaluates a person's readiness to perform a healthier behaviour and provides strategies to guide the process of change to the person. This model proposes five stages of behavioural change: pre-contemplation, contemplation, preparation, action, and maintenance. Diez-Canseco et al. further grouped these five stages into three when designing their mHealth services [229]. In the first stage of pre-contemplation and contemplation, they provided information about the benefits of change to healthy lifestyles. In the second stage of preparation and action, tips and suggestions were given in regard to behavioural changes towards healthy lifestyles. In the last stage of maintenance, positive reinforcement was used to maintain healthy lifestyles. Guided by TTM, 64 SMS text messages were designed to promote healthy lifestyles in four themes: low sodium intake, vegetable and fruit intake, reducing high sugar and fat food intake, and physical activity. In one-year field validation by 108 participants in three Latin American countries, 56 SMS text messages gained very high rates of understanding and appeal for behavioural change in self-management of hypertension. Hacking et al. provided the patients in the IG with 90 SMS text messages over 17 weeks. The messages included knowledge about hypertension and healthy lifestyle suggestions. The patients in the CG received standard care without any SMS text message [223]. At the end of the intervention, although there was no significant difference in overall health knowledge between the two groups, the participants in the

IG reported increases in the self-reported behavioural changes. This suggested that the SMS text messages had acted more like a reminder instead of providing new information. Therefore, they suggested that SMS text messaging worked well for moving from the precontemplation stage to the contemplation or preparation stage. However, it was not certain whether it had any effect on moving the patients into the real action stage of changing behaviour.

Technology acceptance model

Technology Acceptance Model (TAM) was reported in only one study [230]. The TAM models how a user accepts and uses a new technology [228]. It suggests that the perceived ease-of-use and perceived usefulness are the two major factors that influence a user's acceptability of new technology. Rhoads et al. conducted a pilot trial to evaluate the effects of using mHealth services for remote monitoring of postpartum women with hypertension [230]. The users were given mHealth devices to monitor their BP, weight, pulse, and oxygen saturation over a two-week period. At the end of the intervention, two TAM-related variables were measured: technology anxiety and facilitating conditions. These two variables were used to measure perceived ease-of-use. Although there was no significant difference between users and nonusers in terms of technology anxiety, the users scored facilitating conditions higher than the nonusers. Also, the users showed a significant health-related behavioural change, representing a much higher return rate to a medical facility than the nonusers.

4.3.2 The Extent to which These Theories were Reported

The most commonly reported TCS items were (1) Targeted construct mentioned as a predictor of behaviour (9/10); (2) Intervention based on single theory (8/10); and (4) Theory/predictors used to select/develop intervention techniques" (8/10). Other items and their reported frequency were: (5) Theory used to tailor techniques to recipients (6/10); (10) At least one theory-relevant construct is linked to at least one technique (6/10); (6) All techniques are linked to at least one theory-relevant construct (4/10); (7) At least one technique is linked to at least one theory-relevant construct (4/10); (8) Group of techniques are linked to group of constructs (4/10); (11) Theory-relevant constructs are measured: post intervention (4/10); (18) Results discussed in relation to theory (4/10); (12) Theory-relevant constructs are measured: post and pre-intervention (3/10); (13) Changes in measured theory-relevant constructs or predictors (3/10); (19) Appropriate support for theory (3/10); (14) Mediator predicts the dependent variable (2/10); (15) Mediator predicts dependent variable, controlling for independent variable (2/10); (9) All theory-relevant constructs are linked to at least one technique (1/10); (17) Mediated effect is statistically significant (2/10); (3) Theory used to select recipients (0/10); (16) Intervention does not predict dependent variable when controlling independent variable (0/10); (20) Results used to add/remove constructs (0/10); and (21) Results used to specify interrelationships between constructs should be changed (0/10).

The mean scores of the six categories were shown in Table 1. "Reference to underpinning theory" were reported to a large extent. "Refining theory" got zero marks; namely, none of the included studies reported refinement of a theory.

Table 4-1 Frequency of studies that cover a particular category in the Theory Coding Scheme

Theory coding scheme category [215]	**Item**	**Mean score (%)**
Reference to underpinning theory	(1), (2)	1.7/2 (85)
Targeting of relevant theoretical constructs	(1), (4), (6)-(10)	4.2/7 (60)
Using theory to select recipients or tailor interventions	(4), (6)	0.6/2 (30)
Measurement of constructs	(11), (12)	0.7/2 (35)
Testing of mediation effects	(11)-(19)	2.3/9 (26)
Refining theory	(20), (21)	0/2 (0)

4.4 Discussion

There is limited reporting of theory used to support mHealth services for patient self-management of hypertension [12]. We conducted a mix-method literature review on ten studies to investigate this significant question. We found that the most commonly reported theories are HBM and SCT; other reported theories are SDT, TPB, TTM and TAM.

In terms of the extent of reporting, most studies only mentioned the use of theory rather than deeply discussed the extent and effect of use. Several studies described the relevant theoretical constructs. Only a few studies used theory to select recipients, tailor interventions, measure constructs, or test mediation effects. No study reported refining theory. This is consistent with the findings of a meta-regression conducted by Garnett et al., which investigated how mHealth services reduced unhealthy alcohol consumption [206]. Prestwich et al. also found that near 90% of health interventions did not report the use of theory [231]. However, we cannot conclude that those interventions are not based on any theory. There may be two major reasons for this phenomenon. First, although not elaborated, some theories may be unconsciously applied to the design of such interventions as they were integrated into people's common sense. For example, Sun et al. did not explicitly report the use of the TPB in their intervention design process, but their intervention "BP Tagger" was aimed at motivating patients to focus attention on the abnormal BP readings and to identify factors that result in BP fluctuation. This design, in fact, was in accordance with TPB because it promoted patient-perceived behavioural control [227]. Second, the constructs can be overlap in different theories. For instance, self-efficacy is the construct in both the SCT and the HBM. Therefore, the report of theory use in mHealth service is probably not systematic nor comprehensive.

This literature review, for the first time, investigated the theory used in mHealth services for patient self-management of hypertension. It provides insights into these theories. First, the HBM, SCT, SDT, TPB, TTM and TAM can help the design and evaluate the mHealth services for self-management of hypertension. Second, although it is quite possible that theories were used unconsciously, they were seldom reported to be used in such hypertension interventions; therefore, there is a pressing need to overcome the challenges proposed by Prestwich et al. [231], which is vital to guide the design, implementation and evaluation of the mHealth services. Third, future research can also focus on designing more robust empirical studies in which more evidence can be collected to refine and optimise the theory to guide future mHealth services.

4.5 Conclusions

This mix-method review identified six commonly used theories to guide mHealth services to support patient self-management of hypertension: HBM, SCT, TPB, TDM, TTM, and TAM. Most studies only mentioned the use of theory. Several studies described the relevant theoretical constructs. Only a few studies used theory to select recipients, tailor interventions, measure constructs, or test mediation effects. No study reported refinement of the theories. Although mHealth services provide a unique opportunity to develop and refine theories, there is still a lack of reports on such a process in their application to self-management of chronic conditions. Therefore, more attention must be paid to the careful selection, application and reporting of the use of theory to accurately evaluate the value of the theory to the outcomes of mobile health. Our findings are useful for improving the design of mobile health services that support patient self-management of hypertension and other chronic conditions.

Summary

This chapter contributes further theoretical discussions about Research Question 1. The applicable theories for the design, implementation and evaluation of mHealth services are discussed in detail. These include six common theories that are often used in mHealth services to guide the management of chronic conditions: Health Belief Model, Social Cognitive Theory, Theory of Planned Behaviour, Self-determination Theory, Transtheoretical Model and Technology Acceptance Model. Most studies only mentioned the name of the theory that was applied. A number of studies described the relevant theoretical constructs. However, further details are required about how the theory was applied to guide the selection of mHealth recipients, intervention design, evaluation, or outcome measurement. No study has ever reported any further refinement of the theories. Therefore, the findings suggested that more attention should be paid to the careful selection, application and reporting of the use of theory [231] and the derived outcomes for any empirical research.

Chapter 5

A Comprehensive 6A Framework to Support Patient Self-Management of Chronic Conditions Using mHealth Services: A Qualitative Thematic Analysis

Forward

After proposing a conceptual framework of five structural components to achieve three benefits of mHealth services that support patient self-management of chronic conditions in Chapters 3, Chapter 4 reported a rapid review of the use of behavioural theory to design, implement and evaluate mHealth services to support patient self-management of chronic conditions. This chapter provides answers to Research Question 2, i.e., what is the mechanism of mHealth services to support patient self-management of chronic conditions. Through an empirical investigation of the patients' perceptions of a mHealth app to support their self-management of hypertension, a 6A framework was derived to explain the mechanisms for the mHealth service to support patient self-management of chronic conditions.

This chapter is a reproduction in full of the paper "A comprehensive 6A framework for improving patient self-management of hypertension using mHealth services: Qualitative thematic analysis" authored by **Ting Song**, Fang Liu, Ning Deng, Siyu Qian, Tingru Cui, Yingping Guan, Leonard Arnolda, Zhenyu Zhang and Ping Yu, and published in *Journal of Medical Internet Research* 23, no.6 (2021): e25522.

The numbers of figures, tables, sub-headings and appendices have been re-numbered to keep the coherence of this thesis.

Abstract

Background: Hypertension affects over 15% of the world's population and is a significant global public health and socioeconomic challenge. Mobile health (mHealth) services have been increasingly introduced to support hypertensive patients to improve self-management behaviours, i.e. adherence to pharmacotherapy and lifestyle modifications.

Objective: This study aims to explore patient perceptions of the mHealth service and the mechanisms for the services to support them to self-manage hypertension.

Methods: A semi-structured, in-depth interview study was conducted with 22 outpatients of the General Hospital of Ningxia Medical University from March to May 2019. The hospital had introduced a mHealth service to support community-dwelling outpatients with self-management of hypertension since 2015. Content analysis was conducted following a grounded theory approach for inductive thematic extraction. Constant comparison and categorisation classified the first-level codes with similar meanings into higher-level themes.

Results: The patient-perceived mechanism for the mHealth service to support their self-management of hypertension is summarised as six 'A's: access, assessment, assistance, awareness, ability, and activation. With the portability of mobile phones and digitisation of information, the mHealth service provided the outpatients with easy access to assess their vital signs and self-management behaviours. The assessment results gave the patients real-time awareness of their health conditions and self-management performance, activating their self-management behaviours. The mHealth service also gave the outpatients access to assistance which included health education and self-management reminders. Both types of assistance could also be activated by abnormal assessment results, i.e. uncontrolled or deteriorating blood pressure value, discomfort symptoms, or not using the system for a long period. With its scalable usage to handle any possible information and services, the mHealth service provided the outpatients with educational materials to learn at their own pace. This led to an improvement in self-management awareness and ability, again activating their self-management behaviours. The patients would like to see further improvement in the application to provide more useful, personalised information and reliable services.

Conclusions: The mHealth service extended the traditional hypertension care model beyond the hospital and clinician's office. It provided the outpatients with easy access to otherwise inaccessible hypertension management services. This led to process improvement for outpatients to access health assessment and healthcare assistance and improved their awareness and self-management ability, which activated their hypertension self-management behaviours. Future study can apply the 6A framework to guide the design, implementation and evaluation of mHealth services for outpatients to self-manage chronic conditions.

Keywords: patient experience; mHealth; mobile app; intervention; self-management; high blood pressure; chronic disease management; qualitative research

5.1 Introduction

5.1.1 Background

Hypertension is one of the principal modifiable risk factors for cardiovascular diseases, especially for stroke, and chronic renal diseases [210]. Without clear pathophysiology or cure, it remains the major global burden of morbidity and mortality. Alarmingly, rising living standards and their derived unhealthy lifestyle accelerate the prevalence of hypertension year by year. In 2015, an estimated 1.13 billion people worldwide had hypertension, leading to 19% of global deaths [64, 211]. Hypertension also imposes a substantial economic burden on society and healthcare systems.

The annual medical cost of hypertension is estimated at 370 billion US dollars worldwide, representing approximately 10% of global healthcare expenditure [212]. Hypertension control is, thus, a priority for improving population health and containing chronic condition burden.

Hypertension treatment includes both pharmacological and non-pharmacological interventions [232]. These interventions are only effective if a patient engages in long-term, even lifelong, self-management behaviours, including adherence to pharmacotherapy and lifestyle modifications. Patients need to take antihypertensive medication as often as prescribed and to regularly measure blood pressure (BP) to monitor its efficacy [64]; they also need to follow a healthy lifestyle, i.e., maintaining a healthy diet, doing physical activities, avoiding tobacco and unhealthy alcohol use, and managing mental stress [64, 233]. These self-management behaviours, however, are challenging to adhere to for most patients. Less than 50% of patients adhere to hypertension self-management one year after initiating pharmacotherapy [119]. Non-adherent behaviours include failure to initiate pharmacotherapy and lifestyle modifications, to take antihypertensive drugs at the prescribed frequency, to adhere to long-term treatment, and to monitor efficacy regularly [9, 10]. These challenges can be addressed by assistive technology innovations, such as mobile health (mHealth) services.

5.1.2 Mobile Health Services

Mobile health refers to the use of mobile devices to deliver medical or public health services [20]. As mHealth services break the constraints of time, space, cost and capacity, they can provide patients with low-cost, affordable, ongoing support to manage their chronic conditions, such as hypertension, which require long-term lifestyle-related care plans and continuous monitoring in the home environment [37]. Mobile health services have multiple modes, e.g., SMS text messages, mobile apps and interactive voice response [234]. With the proliferation of smartphones and the advancement of cellular networks, mHealth apps are increasingly available for patients to access healthcare services. In 2018, approximately 318,000 mHealth apps were available worldwide [235].

The effectiveness of mHealth services to assist patient self-management of hypertension has been widely studied. Empirical evidence suggests that mHealth services can better assist the patients to control BP than the conventional face-to-face care model [121-126]. A review of 23 studies on the effectiveness of mHealth services found that 16 (69.6%) studies demonstrated a positive effect on medication adherence and healthy behavioural modification [117]. Lu et al. also found that mHealth apps can improve patient experience, especially in health information exchange, physician-patient communication, and short-term outcome improvement [236]. Nevertheless, after assessing 186 hypertension-targeted apps in Apple and Google Play stores, Alessa et al. found that only 30 apps (16%) were likely to be effective in assisting hypertension self-management [34]. The common feature of these 30 apps was that they all had three or more functionalities, including (but not limited to) self-monitoring, reminders, and educational information or automatic feedback. There was little information about the theoretical basis of many apps nor any evidence about their effectiveness and usability. Song et al. also found that the ineffectiveness of the mHealth service might result from a lack of theoretical guide for assisting behavioural modifications [140]. Hallberg et al. interviewed 49 patients who used an interactive mobile phone-based system to self-manage hypertension [27]. The patients appraised the system as providing a useful tool for self-reporting health conditions, measuring BP, retrieving self-reported data, and receiving motivational messages. These had led to improvements in lifestyle, health knowledge and better engagement. However, as the participating patients were all active mobile app users, this study may be susceptible to positive bias. Conversely, Morrissey et al. doubted the sustainability of mHealth services despite positive patient engagement [30]. To date, it is not clear about the mechanism for mHealth services to assist patients with self-management of hypertension.

5.1.3 Study Context and Aim

To pilot trial a mHealth service to improve patient hypertension management and population health, a large-scope, international, tri-partite, collaborative program was conducted between the University of Wollongong, Australia, Zhejiang University, and the General Hospital of Ningxia Medical University, China through a formal research partnership. The mHealth service entitled 'BP Assistant' was developed by the Biomedical Informatics Laboratory at Zhejiang University to support patients to self-manage hypertension in Ningxia, a province in China with a high prevalence of hypertension due to high-salt intake [125]. It was implemented in the General Hospital of Ningxia Medical University, the only tertiary hospital in the province, in November 2015. The hospital has over 3,000 beds and supports patients self-management of hypertension. Up to March 2019, 2,079 patients were enrolled in the mHealth management program. This study explored patient perceptions of the mHealth service and the service mechanisms to support them to self-manage hypertension.

5.2 Methods

5.2.1 Ethics Approval

The Human Research Ethics Committee of the General Hospital of Ningxia Medical University, China, approved this study. The registration number is ID2018-325. Oral and written consents were obtained from all the participants before the interviews, and their anonymity was preserved. All information and audio recordings about participants are kept confidential.

5.2.2 Study Design, Setting, and Participants

This qualitative study was conducted in the Department of Cardiology at the General Hospital of Ningxia Medical University from March to May 2019 using semi-structured, in-depth interviews. The study population was outpatients with hypertension who were registered to receive the mHealth service provided by this department. All participants had taken part in a previous clinical trial (Registration number: ChiCTR1900026437) that evaluated the effectiveness of the service.

5.2.3 The Mobile Health Service

The mHealth service includes two technical components: a smartphone-based app, entitled BP Assistant, for patients to use to self-manage hypertension; and a Web-based portal for healthcare providers to monitor and communicate with their patients. The app can be used in both iOS and Android systems. There are six key functional modules in the app: health education, health management plan, health check-up, health report, reminder service, and performance ranking (see Table 5-1).

Table 5-1 Six key functional modules of BP Assistant

Functional module	Features
Health education	to provide educational information about hypertension and hypertension management
Health management plan	to provide a to-do list that requires users to record and upload personal health data, including BP and heart rate, medication type and dose, weight, diet, exercise and uncomfortable symptoms
Health check-up	to provide feedback to tell users whether their BP is abnormal or not
Health report	to provide visual daily and monthly reports based on a statistical analysis of input data
Reminder service	to allow users to set up and receive tailored reminders for health management plans
Performance ranking	to score and rank each user's performance according to their degree of app use in a ranking list

Healthcare providers can check all the uploaded data from the Web-based portal whenever needed. In particular, if an anomaly was detected, such as a sudden change in vital signs, long-term loss of contact, or patient-reported discomfort, the system would automatically send out a warning signal to alert the healthcare providers to follow up with the patient and to provide treatment assistance or guidance.

5.2.4 Semi-structured Interview Questions

The interview guide was developed by the first author in English and then translated into Chinese. The content validity was evaluated by a panel of ten bilingual experts, including four cardiovascular medical specialists, four health informatics experts, one certified health manager and one information systems expert before translating back into English. Afterwards, it was pilot tested for its face validity by three hypertensive patients who had used the app. Feedback from these patients was taken to further refine the interview guide to improve the understandability and relevance of each question (see Appendix B).

5.2.5 Sampling and Recruitment

Participants were selected using purposive, snowball, and theoretical sampling until the data was saturated, i.e., no new themes emerged [237-239]. We purposefully selected participants with varying sociodemographic characteristics to ensure diversity in age, gender, and type of mobile operating systems being used. Theoretical sampling, which involves simultaneously collecting, coding, and analyzing data to determine whom to approach next to generate new insights, was used to enrich emerging categories and provide guidance for data collection to reduce selection bias.

Participants who (1) were aged 18 years and over, (2) had a diagnosed essential hypertension (hypertension without identifiable causes) based on the Seventh Report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure [5], and (3) participated in the program to self-manage hypertension using the BP Assistant over three months, were included to the study. Participants who (1) had secondary hypertension or (2) were unable to express their own perceptions due to mental disabilities or inability to speak were excluded from the study.

Potential participants were contacted by a registered nurse through a phone call or in a waiting room while they were waiting for a medical consultation. They were informed about the purpose and requirements of the study and then sought verbal consent. An interview appointment was then made with those who provided verbal consent. At the beginning of the appointment, the interviewer described a detailed interview process and sought written consent. Only those who provided written consent were interviewed.

5.2.6 Data Collection

After providing the written consent, a participant was guided into a reception room where the interview was conducted. After briefing the participant on the purpose, procedure and content of the interview, the interview started. Each interview lasted around 30 minutes and concluded when information saturation was reached. The audio recordings were transcribed verbatim into Microsoft Word documents. All names included in the manuscript were replaced by codes to preserve the anonymity and privacy of the participants. All information and audio recordings about the participants were kept confidential.

5.2.7 Data Analysis

The interview transcripts were systematically analysed using the inductive thematic analysis method in order to identify different points of view and grouping them into various themes [240, 241]. Three researchers were engaged in content analysis. Each transcript was read carefully to get a general impression of the main experience of the participants by two researchers (TS and SQ). Content analysis followed the Grounded Theory approach [242, 243]. The coding and classification were conducted in Microsoft Excel, benefiting from its affordance of easy visualisation of a large number of codes in one screen, which was convenient for constant comparison, classification and aggregation of codes, as suggested by Bree et al. [244]. Each document was divided into sentences that only address one issue and allocated to different cells in the same column. Each sentence was critically analysed verbatim to identify the meaning unit by one researcher (TS), i.e., an atomic text fragment containing relevant information to elucidate the research question. Given the different ways in which the participants expressed their experiences, each unit of experience was tagged with a label expressing its core meaning. This resulted in the abstraction of the initial codes to describe these experiences.

The initial codes were compared, aggregated, and sorted into 16 higher conceptual level concepts, known as subthemes. In this stage, how the patients were affected by the mHealth service were also established to understand the relationships. After that, the concepts with similar meaning were further abstracted and grouped into an overarching six categories, called themes. After more than three months of constant comparison, aggregation, classification and discussion, the tentative coding and data management were iteratively formulated and revised according to the consensus among the four researchers to avoid duplication and overlap (see Table 5-2). The coding was then validated by another researcher (SQ), and the third researcher (PY) was referred to for arbitration when inconsistencies occurred.

Table 5-2 Examples of Initial codes, subthemes and themes generated from the interview

Quotation	Initial code	Subtheme	Theme
It is very convenient (when I am) outside (such as) going abroad. It can be taken and used everywhere.	Convenient to use outside	Portability	Access
	Convenient to use when going abroad	Portability	Access
	Can be taken and used everywhere	Portability	Access
Just won't forget it. I used to forget about (taking medication on time). Now once the alarm rings, I will take the medications.	Not forget	Reminder	Assistance
	Take medicine on time when the alarm rings	Cue to action	Activation
I used to think hypertension was not a problem. (But) the cases (provided in the app) awaked me. It is my own business to manage my daily life.	Not a problem	Misperception	Awareness
	Cases	Health education	Assistance
	Own business	Importance of self-management	Awareness

5.3 Results

5.3.1 Demographics

Twenty-two hypertensive outpatients (four females, 18.2%) participated in this study. Their age ranged from 33 to 73 years, with a median of 47 years. They were employed (n=11, 50%), self-employed (n=7, 32%), retired (n=3, 13.5%), or unemployed (n=1, 4.5%). Nine participants (40.9%) had a Bachelor's degree and above. Six (27.3%) had a college degree. Five (22.7%) held senior high school diplomas, and two (9.1%) held junior high school diplomas. Twelve participants (54.5%) used iPhones, eight (36.4%) used Android smartphones, and two used both (9.1%).

5.3.2 A 6A Framework that Explains the Mechanism for the mHealth Service to Support Patient Self-Management of Hypertension

The patients' perception of the mHealth service on their hypertension self-management are summarised in six themes (6A): access, assessment, assistance, awareness, ability, and activation (see Figure 5-1).

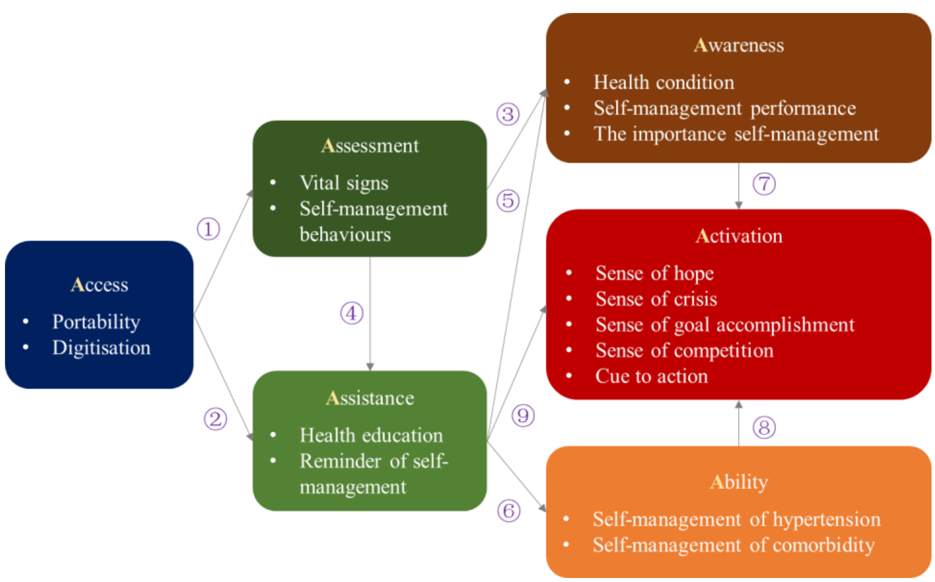

Figure 5-1 A 6A framework of using the mHealth service to support patient self-management of hypertension

With the portability of mobile phones and digitisation of information, the mHealth service provided hypertensive outpatients with low-threshold "access" to health "assessment" ① and healthcare "assistance" ②. The assessment results, i.e. vital signs and self-management behaviours, gave the patients real-time "awareness" of health conditions and self-management performance ③. In particular, abnormal results, such as deterioration of vital signs or lack of self-management behaviour records, could also be fed back to healthcare providers to provide the patients with "assistance" ④. Healthcare "assistance" included health education and reminders of self-management behaviours. Health education assisted the patients in improving their "awareness" of the importance of self-management ⑤ and the "ability", i.e. knowledge and skills ⑥, in performing self-management behaviours. The reminders assisted the patients in overcoming the barrier of forgetfulness. The improvement of self-management awareness ⑦, ability ⑧, and reminders ⑨ together "activated" their self-management behaviours.

In descending order of the number of times mentioned by the interview participants, the 16 subthemes are vital sign assessment, health education, ability to self-manage hypertension, digitisation, a reminder of self-management, awareness of health condition, cue to action, portability, self-management behaviours assessment, awareness of the importance of self-management, sense of goal accomplishment, sense of hope, sense of crisis, awareness of self-management performance, sense of competition, and ability to self-manage comorbidities (see Figure 5-2).

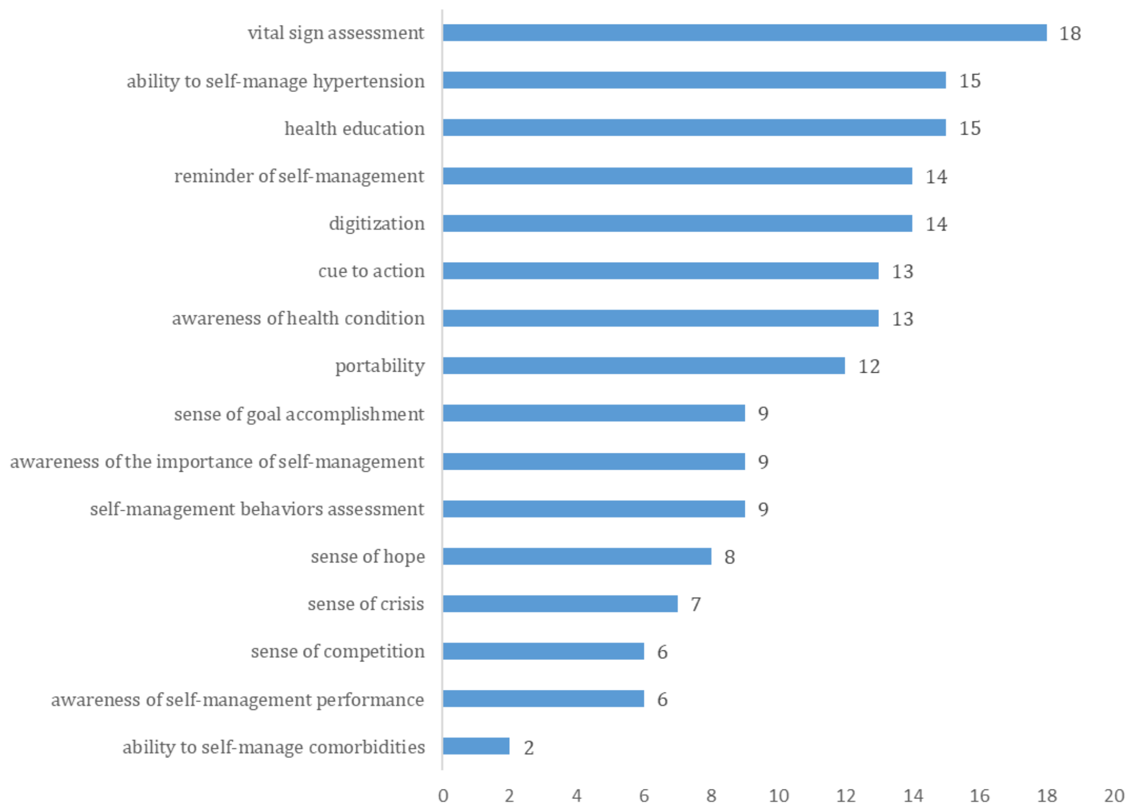

Figure 5-2 The number of times each subtheme was mentioned by the participants in the interviews

Access

The patients appreciated that the mHealth service lowered their threshold to access health information and healthcare services compared to the conventional hypertension care model. This was due to the portability of mobile phones and the digitisation of information.

Portability. The use of the mHealth service for hypertension self-management was available through the smartphones the patients carried with them in daily life. The lightweight, portable smartphones made it convenient for them to access health assessment and healthcare assistance without time and space limits. The patients could keep their healthcare providers informed of their health conditions through access to the app. The remote communication and interaction reduced their need for hospital visits, avoiding excessive registration and examination costs.

It is very convenient (when I am) outside (such as) going abroad. It can be taken and used everywhere. (Patient 09)

It's easier to communicate about hypertension management (with my doctor) because (if) there is always some tool to connect between us to exchange information, (I) do not have to run to the hospital. It has always been annoying to go to the hospital to seek medical treatment. We have to wait in a crowded space for a long time, and the queue is often quite long. Health problems that could be solved in a few minutes always took a whole morning. (Patient 18)

Digitisation. The mHealth service provided the patients with a convenient digital platform to access health information and healthcare services. The data were in digital form and stored in the app, which was easier to retrieve and less likely to be lost than the traditional method of recording data in a notebook. It was also quicker and easier to review the records without flicking through paper-based records, allowing both patients and their healthcare providers to capture the useful information in time.

In every record, the specific time was recorded; the specific data was also recorded, … unlike writing it down in a notebook, it won't be lost. (Patient 06)

It's so convenient that I can track my records easily, …, unlike before, if I needed to identify a certain record, I had to go through all written records one by one. (Patient 14)

(It is) more convenient. I used to record my BP in a notebook, every time the doctor had to flip through it and read the records one by one. You see, it is impossible for her to read each record and identify my highest systolic BP. As she has to see so many patients in a day, in fact, she cannot get anything (meaningful). … (But) now she only needs to glance

at the curve, the overall trend, the peaks and valleys directly on the mobile phone. This is faster and more intuitive. (Patient 02)

Assessment

The patients praised the mHealth service because it provided them with the opportunity to assess their vital signs and self-management behaviour.

Vital signs. The mHealth service assessed the patients' vital signs, i.e. BP and heart rate, measured and entered by themselves on the app through automatic analysis with the results presented back to both the patients and their healthcare providers. The patients believed that these results provided evidence enabling their healthcare providers to understand their condition, to make an appropriate diagnosis and to provide feedback, such as adjusting the treatment program, instead of relying on a single measurement of BP in the clinic.

> *(The app) helped me to tweak my medicine well, … My medication had been changed four times before because my BP reading was always up and down. I did not have any records at that time. … With the app, the doctor prescribed the medicine in reference to all the records of my BP. Once the medication was right, the BP was gradually under control. (Patient 11)*

One patient specifically pointed out that the mHealth service helped to solve his "white-coat" effect in the clinic.

> *…, my BP readings are always higher when I sit with the doctor but lower at home. So, the data I upload (to the app) is more accurate than that taken in the hospital. (Patient 09)*

Self-management behaviour. The mHealth service automatically recorded the patients' self-management behaviours, including BP, heart rate and weight measurement, medicine intake, step count and food intake, to assess their self-management performance. The patients thought that the assessment results provided their healthcare providers with evidence to determine the reason for the suboptimal efficacy, i.e. whether the medicine was inappropriate or the patients did not adhere to the self-management.

> *In the past, if the BP was not well controlled, the doctors would ask me if I take medicine on time or if there was too much salt intake or I did not do exercise. With the record, she can immediately see what might cause poor BP control. (Patient 17)*

In particular, abnormal assessment results, i.e. uncontrolled or deteriorating BP values, discomfort symptoms, or not using the system for a long period, could also be detected by the mHealth system. Once an abnormal result was detected, the mHealth system would send an alarm signal to notify the healthcare provider to contact the patient or his/her families to provide timely feedback.

> *… (The health manager) called me in time and asked me what happened recently; why wasn't my BP controlled but suddenly increased? Did I eat high cholesterol food etc. … (it) is a wake-up call to us. (Patient 07)*

The negative experiences reported by the patients included overwhelming assessment items, inaccurate assessment of health status, and inability to see how lifestyle changes impact on BP level. Some patients complained that the app required too many data items to be entered on a daily basis, which they doubted about the actual effect on disease management but saw it as wasting their time.

> *Some functions are useless. For example, I take the same drugs every day. Why do I need to upload them every day? (Patient12)*

I only use (hypertension-)related functions. Also, it's hard to assess, i.e., the diet. For example, if I record a bowl of rice, you still don't know exactly how much rice I eat. (Patient07)

Some patients considered some wordings in the app, such as BP and discomfort symptoms, were not entirely accurate.

Your assessment of discomfort symptoms is inaccurate and illogical. The symptoms listed in the app, such as chest pain and mixed-up words, are typical symptoms of cardio/cerebral infarction. How can I still stay at home and wait for feedback once they occur? I must have to directly go to the hospital or call the emergency. If you say sweating, a little dizzy, these can be called discomfort symptoms. (Patient02)

The assessment of BP is unscientific without considering the pressure difference. I remember one time, I felt particularly uncomfortable, and my BP was 100/80 (mmHg). The app showed unexpectedly that my BP was normal. This would mislead the patient. (Patient12)

One patient strongly felt a lack of logical connection between the assessment results, e.g., BP value and other data items. This impeded a patient's recognition of the importance of certain app functions for hypertension management, thus reducing their acceptance and use of these functions.

The assessment indicators (in the app) are all isolated. We can't see any connection between what we do and the corresponding outcomes. (Patient09)

Assistance

The patients reported two types of assistance provided by the mHealth service: health education and reminders.

Health education. The patients acknowledged that their physicians had explained, more or less, the reason and the way to self-manage hypertension; however, they either did not fully understand or ignored these instructions during the medical consultation period. The mHealth service assisted them with this challenge because it provided a large volume of educational materials that were not otherwise accessible, which allowed them to learn at their own pace so as to absorb the information and to truly understand the meaning of the medical orders.

> *Yes, (the doctor) told me before. But, he/she may not go into the level of detail due to the time limit. (I) didn't take it to heart either (because I) only paid attention to what medications were (at the time of medical consultation). (Patient 18)*

> *…the doctor had told me everything (about self-management of hypertension) when I was sitting with her. But I had little knowledge and did not really absorb the information. When encountering the same information again (in the app), I came to understand why and how to (do it). (Patient 03)*

The patients also felt the content provided by the mHealth service was more trustworthy than those obtained from other sources because it was disease-focused and recommended by the healthcare professionals in a prestigious tertiary hospital.

> *… although it is much easier to get the (hypertension-related) information from other sources, such as TV, mobile phone, newspapers, your app is more trustworthy because it is targeted, specifically for hypertension and it's sophisticated. Also, (it is) professional because (the content is) checked by doctors, unlike information (from other sources which was) just copied and pasted (from somewhere else). (They) cannot be trusted. (Patient 02)*

Reminders. The mHealth service reminded them to perform necessary self-management actions, e.g., taking medications, which assisted them in overcoming the barrier of forgetfulness.

> *Just won't forget it. I used to forget about (taking medication on time). Now once the alarm rings, I will take the medications. (Patient 09)*

The negative experiences mentioned included that the feedback service was lagged behind and untimely because they had experienced symptoms and discomfort without receiving any feedback.

> *… I felt chest pain at one time, and I reported it in the app. But there was no response. (Patient22)*

There were also complaints about the technical instability of the app, preventing the patient from getting assistance in time.

> *Sometimes I can't log into my account. You know, users will lose confidence in your product in this case. (Patient15)*
>
> *Occasionally, it may fall offline. (Patient13)*

Awareness

The patients felt their awareness was improved by using the mHealth service, which included awareness of their health status, self-management performance and the importance of self-management.

Health status and self-management performance. The visual and colourful graphic assessment results charts for vital signs and self-management behaviours improved patients' awareness of their health status and self-management performance, respectively.

… then translate (the assessment results) to a graph. I was more aware (of my health condition) as soon as I looked at the chart. My BP, for example, showed a downward trend but had not met the target. (Patient 02)

It has several indicators in different colours, it's very vivid, clear at a glance. (Patient 05)

The importance of self-management. Despite being diagnosed with hypertension, some patients never took it seriously because they did not believe in the consequences of the disease, nor the need to control it. The patients admitted that the educational materials assisted them with a better understanding of hypertension-related risk factors and corresponding consequences and built their belief in the responsibility of self-management. This made them change their attitudes, being aware of the importance of self-management, and thus had the intention to perform self-management behaviours.

When diagnosed with hypertension after a medical examination, I thought the doctor just scared me because I didn't feel anything wrong with my health. I ate and drank and smoked whatever and whenever I wanted, and even didn't take any medication because I was afraid of side-effect. After reading the materials in the app, I knew I was wrong. It was time to manage hypertension. (Patient 19)

I have never managed (hypertension) before (using the app because) I thought many of my family and friends also had (it), but they were still alive and well. Now I know that once there are symptoms, it is late because our organs have been injured, and the injury was mostly irreversible. (Patient 04)

I used to think hypertension was not a problem. If (I felt) dizzy, (then I) go to see a doctor; otherwise, just let it be. (But) the cases (provided in the app) awaked me. It is my own business to manage my daily life. (Patient 18)

Ability

Patients reported that using the mHealth service improved their ability to self-manage hypertension, which included their knowledge and skills in hypertension self-management and inspiration for self-management of comorbidities.

Knowledge and skills in self-management of hypertension. The health education provided by the mHealth service increased patients' general knowledge of hypertension self-management and also improved their BP control skills and strategies for practising healthy lifestyles.

The health tips are quite useful, (I) got to know what should (I) pay attention to in daily life, and how to achieve self-regulation; for example, I often remind myself not to be angry, to maintain a healthy diet, and to do physical activities. (Patient 15)

… I went through the educational material little by little, such as how to measure BP correctly at home, what matters when taking antihypertensive drugs, etc. Now, I know how to self-manage (hypertension) well. (Patient 01)

In particular, one patient mentioned that the mHealth service improved his ability to deal with discomfort symptoms. As he learned about the signs and patterns of the manifested symptoms and the level of severity, he was confident and capable of deciding whether to wait and see or to seek medical assistance immediately.

…The educational materials are quite useful. … (For example, previously) I always rushed to the emergency department when I felt dizzy or heart palpitations because I had no idea

what happened. But now, what I usually do is taking out a gauge to measure my BP and heart rate; if they are abnormal, I will observe it for a while. Usually, they would return to normal without doing anything. Otherwise, I would see the doctor. In addition, I used to be very anxious when this case happened, which made my BP higher; but now, I always remind myself to be calm, making a rational decision after observation. (Patient 05)

Inspiration for self-management of comorbidities. The mHealth service also improved patients' ability to self-manage comorbidities because there were similar requirements for the management of chronic conditions.

Although this (app) is hypertension-focused, it is virtually enlightening to my daily self-management of coronary heart disease and diabetes, such as eating, exercising, medicine adherence, because their management principles are similar and interlinked. (Patient 09)

However, some patients believed that the information provided by the app was not enough to improve their ability due to the content was monotonous, difficult to absorb, and the update was not frequent enough.

The content of health education is monotonous and lack regular updates. (Patient07)

The health education material was not adequate, thus less useful. The information was out of date. (Patient14)

Activation

The patients reported that using the mHealth service activated their self-management behaviours, which included their sense of hope, crisis, goal accomplishment and competition, as well as cues to action.

Sense of hope and crisis. The assessment results of vital signs gave the patients real-time awareness of their health status, thereby activating their sense of hope or crisis. Awareness of improved health status provided a sense of hope for BP control, which encouraged them to maintain self-management behaviours.

> *It brought up a sense of achievement by seeing the curve of my BP recording being flattened. This gives me the motivation to keep going. You see, (My systolic BP) has dropped from 164 (mmHg) to 142 (mmHg). It will be normal once (it) drops to 120 (mmHg). (Patient 05)*

Conversely, awareness of deteriorating health status provided a sense of crisis, which activated them to improve self-management strategies.

> *A curve shown in the app can indicate whether my heart rate is fast, slow or normal today, so as my BP. If abnormal, I was set on alert to reflect upon my own behaviour. Should I get more exercise? Am I eating too much salt? Did I forget to take my medicine? (Patient 14)*

> *… if you don't record (the BP), there is no (data) for comparison. … But if you have recorded and compared yesterday's, today's and tomorrow's records, a sense of crisis will push you to reflect. (For example), my BP is rising. What might have caused it? Oh, probably because I drank alcohol. The record showed my BP was normal before. So I shouldn't drink alcohol in a couple of days; instead, I should pay attention to a healthy diet, regular work and rest. (Patient 15)*

Sense of goal accomplishment and competition. The assessment results of self-management behaviours made the patients aware of the self-management performance of both themselves and other users, thereby activating their senses of goal accomplishment and competition. Persistent recording of patients' self-management efforts had brought them a sense of goal accomplishment.

> *… it would be nice that my effort could be faithfully recorded by your app. I did it without any recording in the past. But now, look at these records. I have the strength (to keep going). (Patient 15)*

> *What I did and not have been recorded (in the app). For example, walking, I was looking through (the records) now and then. (If) I walked 9,000 steps yesterday, I knew I reached the standard and felt at ease. If I did not reach 9000 steps today, I always worried and thought that I should go out and walk more.(Patient 21)*

In particular, two patients mentioned that the performance ranking function enabled activation. When a patient knew that other patients did better than they had done, their sense of competition was switched on, which activated self-management behaviours.

> *Seeing that someone was ahead of me, I made a firm decision that I had to catch up with him/her. (Patient 16)*

Cues to action. The reminder activated the patients' self-management behaviours by providing them with prompts to perform a specific action, e.g., taking medications.

> *…. (the app) always reminds me to take medicine on time. (Patient 18)*

> *(Previously,) the doctor couldn't track my health status, and I wasn't completely sure (about it)…so I was anxious. But now, I was immediately told that I should go to the hospital and take a look at it, which made me felt safe. I felt that I was put on the radar*

screen. They had been paying close attention to me with timely feedback, so I should also play an active role to manage myself well. (Patient 03).

Despite the perceived benefits of activation of self-management, certain patients suggested further improve the incentivising mechanism for using the mHealth services.

> *Actually, (if) you want to encourage them, you have to send a message to list their achievement, such as how many tasks have been completed, how well they controlled (their BP), and how long they have persisted in using the app, etc. (Patient07)*

> *… what can I get? For example, I use another app, and if I walk up to 5,000 steps, it will pop up a message saying, "Congratulations! You have reached 5,000 steps today. Please keep it up". I can't see recognition of what I achieved using this app. (Patient09)*

I don't know the criteria for scoring and ranking the performance, so I'm not motivated because I don't know what to do next. (Patient15)

5.4 Discussion

5.4.1 Principal Results and Comparison with Prior Work

Compared with the traditional hypertension care model, the mechanism for the mHealth service to support patient self-management of hypertension can be summarised in a 6A framework: access, assessment, assistance, awareness, activation and ability (see Figure 5-3).

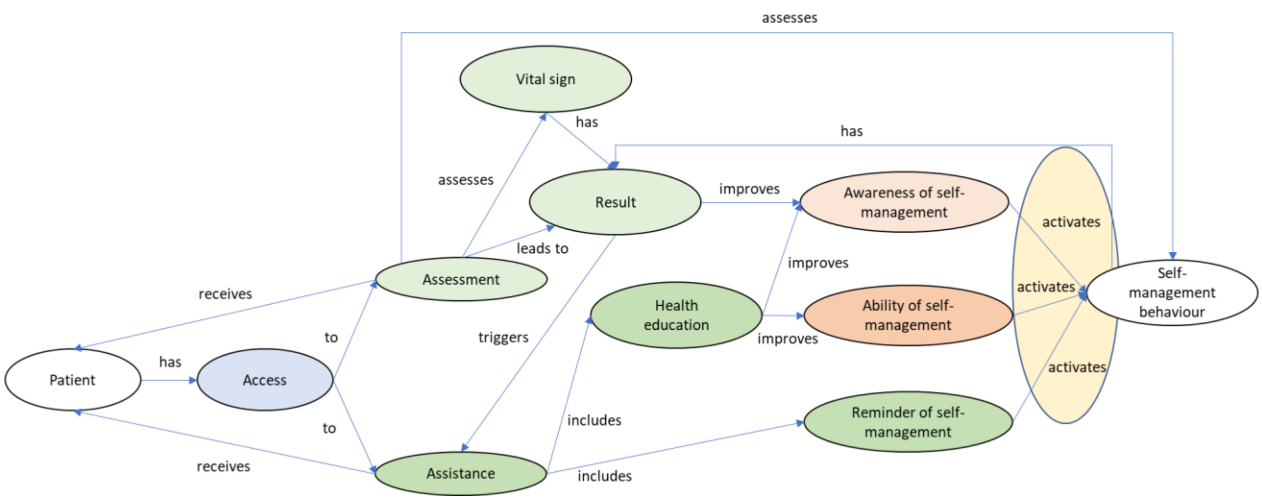

Figure 5-3 The mechanism for the mHealth service to support patients to self-manage hypertension

Our findings can be explained by Donabedian's healthcare quality model [35]. The mHealth service changes the structure, i.e., delivery mode, and process of the traditional hypertension care model. It provides patients with easy access to health assessment and healthcare assistance, which assists with improved self-management awareness and ability. These again activate the self-management behaviours (see Figure 5-4).

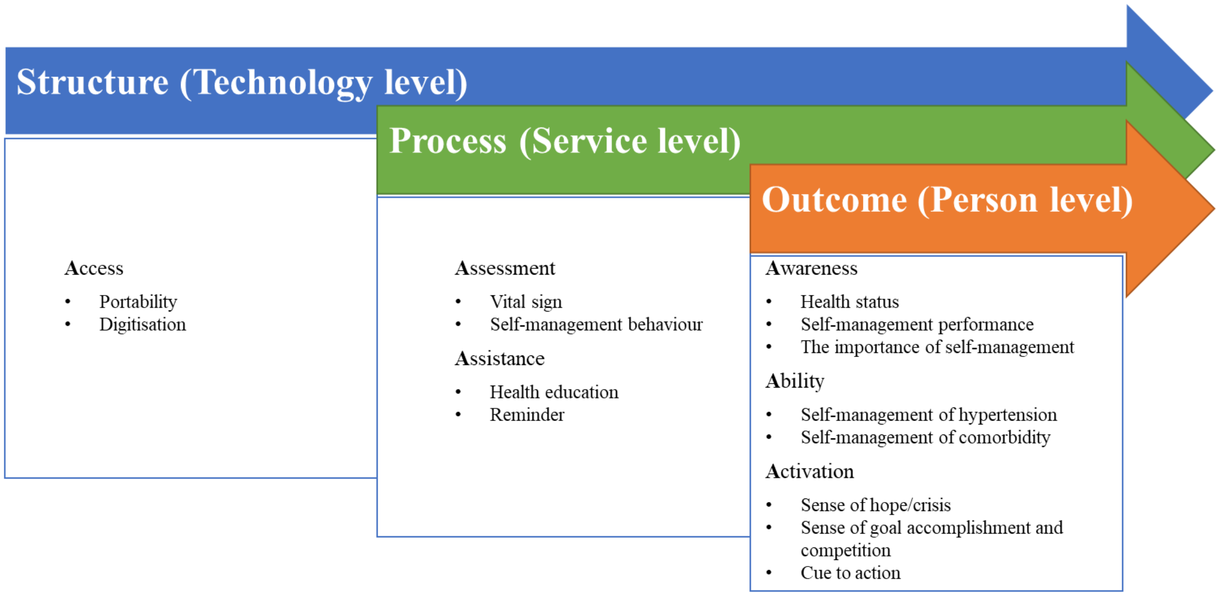

Figure 5-4 Interactions among the structure (access), process (assessment and assistance) and outcome (awareness, ability and activation) in mHealth service for hypertension self-management

The mHealth service enables outpatients to access healthcare services that were previously only available to inpatients. These included the assessment results of vital signs and self-management behaviours, as well as assistance from the mHealth system and healthcare providers. The increased access is not only attributed to the function(s) of the app but also the changes in access right facilitated by the mHealth delivery mode. Computer automation reduces labour costs to facilitate the structural change in the scope of healthcare service delivery beyond the boundary of the hospital. This change in healthcare service structure appears to lead to improved clinical processes [24]. Our patients perceive app use, or smartphone use, as an effective and easy way of gaining access to healthcare services, which facilitates their acceptance and use of the mHealth apps, as found by Anderson et al. [245].

Smartphone portability encourages the patients to interact with the app and extensively use the app functions without geographic boundary and time restriction [246, 247]. The patients also appreciate that the mHealth service lowers the threshold for them to access healthcare service.

They do not need to make a long journey and wait in a long queue to see their healthcare providers, which saves them time and cost.

The mHealth service also improves data access through timely data transfer and easier data retrieval [248, 249]. Vital signs data are presented in easy visual graphics, which allows patients to read the information on a mobile phone at a glance instead of reading it on paper or a computer. As suggested by Hallberg, if the graph can be viewed directly on the mobile phone without connecting to a computer, the mHealth service can be more useful because it addresses the barrier to using the system [250].

Two types of processes are changed: the assessment process and the assistance process. Patients have access to assessing their vital signs and self-management behaviours and the assistance of health education and reminders at home.

The assessment results improve patients' self-awareness of their health status, i.e. "what is my current situation". It also provides evidence to healthcare providers for accurate and timely diagnosis and prescription, as found by Myers et al. [251]. But Den Hond et al. stress that self-measurement of BP cannot replace ambulatory monitoring for clinical diagnosis [252]. Interestingly, the "white-coat effect", i.e., rising BP when seeing a doctor, can distort the real health condition of the patients and lead to misdiagnosis and treatment in face-to-face consultations [253]. Regularly measuring BP at home and recording the results on the app can help solve this problem. This is in line with Barsky et al. 's findings [254]. It is worth noting that some patients report the low accuracy of BP assessment results. If there is a false assessment result, it will inevitably affect the judgment of the severity of the disease and even lead to wrong actions. This indicates that future product development should involve medical experts to ensure the accuracy of the assessment [255].

As suggested by Norman Cousins, "Each patient carries his own doctor inside him" [256]; self-management is essential for all patients with chronic conditions, e.g., hypertension. The first step is to establish awareness and ability. A lack of awareness of the importance of self-management is a major factor causing poor BP control [257]. Bokhour et al. also suggest that hypertensive patients' awareness of factors that affect BP in their daily life may influence their ability to perform self-management behaviours [258]. Our findings suggest that health education has improved patient awareness in health self-management by addressing their "why" questions, i.e. "why is it important to self-manage hypertension". Despite best efforts, limited medical resources and time make the task of educating patients and meeting their individual needs difficult to achieve in traditional face-to-face interventions [259]. The advantage of the mHealth service comes from its high scalability for providing services, e.g., disseminate a large amount of educational material to a wide range of patients with hypertension for effective health education for chronic condition management [118, 260, 261]. It also allows these patients to absorb the information in their own time and at their own pace until they are fully aware of the importance and have the ability to perform self-management. They can also continuously improve their self-management ability by constant learning. This is in accordance with the basic requirements for successful pharmacotherapy and lifestyle management for hypertension [119]. However, some patients were disappointed with the publication frequency, accuracy and legibility of the educational content. This suggests that a successful mHealth service requires accurate resources to be published regularly to sustain the patients' trust with the mHealth service, which was in accordance with Zarea et al. in their study of evaluating health information websites [262]. The negative feedback from the patients also provided insight about what and why the mHealth services did not work, i.e. violating the 6A mechanism.

Awareness of one's health status and self-management performance can activate the person to perform self-management behaviours [263]. This is likely to be achieved through stimulating their sense of hope, crisis, goal accomplishment, and competition, which are the internal driving forces for behaviour. Deteriorating BP changes can enable patients to take responsibility for managing their own health, activating the urge to perform self-management behaviours. This can be explained by the protection motivation theory, which holds that protective motivation is affected by the perceived severity of the disease [264]. A similar phenomenon was found in patient self-management of chronic kidney disease, chronic fatigue syndrome and unhealthy alcohol use [46, 265, 266].

Forgetting to perform self-management is a common problem facing hypertensive patients in daily life. The automatic reminder provides a prompt in solving this problem. It serves as an external driving force to complement the internal driving forces mentioned above. This is in line with the Health Belief Model, suggesting a 'cue' is essential to guide people to perform health-promotion behaviours, especially for the elderly [140, 234, 255].

Our results also corroborate and complement the existing behavioural change theories, such as the COM-B model proposed by Michie [267]. The model describes the interaction between three components, capability, opportunity and motivation, to produce behaviours that, in turn, affect these components. In the COM-B model, "capability (C)", defined as the individual's mental and physical capacity to engage in the related activities, is similar to "ability" in the 6A framework, i.e., the patient's knowledge and skills to perform self-management. "Opportunity (O)" is defined as all external factors that make the behaviour possible or prompt it. This includes access, assessment and assistance provided by the mHealth service in the 6A framework. "Motivation (M)" is defined as all brain processes that can stimulate and guide behaviour, similar to "activation" in the 6A framework, which includes habitual processes (cue to action) and emotional responses (sense of hope/crisis/accomplishment/competition). One step further, the 6A framework highlights the concept of "awareness". This is supported by another behavioural change theory, the Theory of Planned Behaviour (TPB). According to TPB, the premise of behavioural change is the intention to change [268]. In contrast, internal capabilities and external opportunities are not adequate conditions for behavioural change. In the patient's story, it is repeatedly mentioned that the driving force for them to engage in the mHealth service is "awareness" of the need to change and the mechanisms to make the change. Therefore, improving self-awareness is one of the key mechanisms for mHealth service to function.

5.4.2 Limitations

Our findings were drawn from interviews of 22 patients to understand their subjective perceptions of the mHealth service. Therefore, the findings were influenced by their own experience, despite the fact that studying patient perceptions is a rational approach for understanding information system performance [248]. Confinement of the study in a single hospital may limit the generalisability of the results to other settings. There is a limitation in translating the results of a mobile app intervention for hypertension management to other mHealth services media, such as text messaging and interactive voice response [46, 234], or for other chronic conditions, such as diabetes. Different apps can have different functions and delivery format. This suggests the need for further studies on patients' needs and preferences to understand which functions and mode of delivery are most helpful to them. Moreover, the analysis can be difficult to be completely free from a-priori views and knowledge of the hypertension management system of the authors, an inevitable limitation of qualitative content analysis [190, 243, 269]. However, each sentence in the transcripts was read in verbatim to understand the meaning of each participant as neutral and accurate as possible. The verification of the analysis by two more researchers also made up for this limitation as much as possible.

5.5 Conclusions

The mHealth service extended the structure of the traditional hypertension care model beyond the hospital and clinician's office. With its portability and digitisation, the mHealth service provided patients with low-threshold access to communicating with their healthcare providers and receiving healthcare services to support their self-management of hypertension at home. Such structural change in health service delivery has brought process improvement to assist patients' access to effective health assessment and healthcare assistance anytime, anywhere. The improvement in awareness and self-management ability and reminders brought about by such structural, and process changes activated their hypertension self-management behaviours. They would like to see the mHealth service to provide more useful functions and easy-to-use services. Therefore, the comprehensive 6A framework extracted from the in-depth qualitative research theorised the mechanism for the mHealth service to improve patient self-management of hypertension. The mechanism can be further applied to guide the design, implementation and evaluation of mHealth services for outpatients to self-manage chronic conditions.

Summary

This chapter contributes to understanding the process of mHealth services from the perspective of Donabedian's healthcare quality evaluation model [41], thus addressing Research Question 2. The findings are drawn from the interviews with 22 patients about their perceptions of a particular mHealth service that they had used to support their self-management of hypertension. The findings suggest that the mHealth service extends the traditional hypertension care model beyond the hospital and clinician's office. The mechanism for mHealth services to support patient self-management of chronic conditions is summarised into a 6A framework – access, assessment, assistance, awareness, ability and activation. With its portability and digitisation, mHealth services provide patients with low-threshold access to communicating with their healthcare providers and receiving healthcare services to support their self-management behaviour. Such a structural change in health service delivery brings process improvement to assist patients' access to effective health assessment and healthcare assistance anytime, anywhere. The improvement in patient self-management awareness and ability, brought about by such structural and process changes, activate their self-management behaviours. Therefore, the comprehensive 6A framework developed from this qualitative research theorises the mechanism for the mHealth service to improve patient self-management of chronic conditions. The negative experiences of patients contribute to understanding the shortcomings of the service in its design and implementation. These findings have significant implications for further research and clinical practice.

Chapter 6

Measuring Success of Patient's Continuous Use of mHealth Services to Support Their Self-Management of Chronic Conditions: A Theoretical Model and Empirical Test

Forward

Chapter 5 reported the development of a comprehensive 6A framework to explain how mHealth service support patient self-management of chronic conditions through an empirical investigation of the hypertensive patients' perceptions. As management of chronic conditions is a long-term process, it is vital to understand the factors impacting patient intention to continuously use mHealth service to support their self-management of chronic conditions. Therefore, this chapter proposes a predictive model underpinned by the existing theories to explore the patient's intention to continuous use of mHealth services to support their self-management of chronic conditions and reports the findings of a cross-sectional survey to validate the model.

This chapter is a reproduction in full of the paper "Measuring success of patients' continuous use of mobile health services for self-management of chronic conditions: Model development and validation" authored by **Ting Song**, Ning Deng, Tingru Cui, Siyu Qian, Fang Liu, Yingping Guan, and Ping Yu, and published in *Journal of Medical Internet Research* 23, no.7 (2021): e26670.

The numbers of figures, tables, sub-headings and appendices have been re-numbered to keep the coherence of this thesis.

Abstract

Background: Mobile health services are gradually being introduced to support patients' self-management of chronic conditions. The success of these services is contingent upon patients' continuous use of them.

Objective: This study aims to develop a model to measure the success of patients' continuous use of mobile health services for self-management of chronic conditions.

Methods: The proposed model was derived from the Information Systems Continuance Model and Information Systems Success Model. The model contained seven theoretical constructs: information quality, system quality, service quality, perceived usefulness, user satisfaction, perceived health status, and continuous use intention. An online questionnaire survey instrument was developed to test the model. The survey was conducted to collect data from 129 patients who used a mobile health app for hypertension management from 2017 to 2019. The questionnaire items were derived from the validated instruments and were measured by a five-point Likert Scale. The partial least square modelling method was used to test the theoretical model.

Results: The model accounted for 58.5% of the variance in perceived usefulness (R^2=.585), 52.3% of the variance in user satisfaction (R^2=.523), and 41.4% of the variance in patients' intention to make continuous use of mobile health services (R^2=.414). The continuous use intention was significantly influenced by their perceived health status (β=.195, P=.034), the perceived usefulness (β=.307, P=.004) and user satisfaction (β=.254, P=.037) with the mobile health service. Information quality (β=.235, P=.005), system quality (β=.192, P=.022) and service quality (β=.494, P<.001) had a significant positive influence on perceived usefulness, but not on user satisfaction. Perceived usefulness had a significant positive influence on user satisfaction (β=.664, P<.001). In a result opposite to the original hypothesis, perceived health status did not negatively influence patients' intention to continue using the mobile health service but showed a significant, positive correlation.

Conclusions: This study developed a theoretical model to predict and explain patients' continuous use of mobile health services for self-management of chronic conditions and empirically tested the model. Perceived usefulness, user satisfaction and health status contributed to patients' intention to make continuous use of mobile health services for self-managing their chronic conditions.

Keywords: mobile health; service; smartphone; mobile application; continuous use; high blood pressure; chronic disease; PLS

6.1 Introduction

6.1.1 Background

Mobile health (mHealth) services have been increasingly introduced to support patient self-management of chronic conditions over the last decade [49, 270]. They overcome the traditional barriers of time, distance and cost by providing patients with anywhere, anytime access to health information, assessment and assistance [234, 245]. As one of the most commonly used mHealth services, mHealth apps are widely used to record and evaluate patients' vital signs and self-management behaviours, such as medication, exercise and diet; to access health information; to remind self-management behaviours; and to communicate with healthcare providers [49, 270, 271]. With increasing awareness and self-management ability, patients are motivated to self-manage their behaviour, i.e., adhere to treatment, thereby control their chronic conditions and maintain quality of life. Once being used over a long period of time, these apps are likely to result in positive outcomes, such as obvious changes in health behaviours [272, 273].

Despite their potential benefits, mHealth apps are hardly used [116]. Perez finds that 25% of mHealth apps are used only once after installation, and the majority of users stop using these apps after four times of interaction with the apps [274]. A national survey conducted in the US suggests that 45.7% (427/934) of the participants who download certain mHealth apps no longer used these apps [275]. This is contrary to the original intention of introducing these apps to help manage long-term diseases because short-term use is not sufficient to achieve the expected benefits [276, 277]. Therefore, it is essential to understand the factors that affect patients' continuous use of mHealth apps.

Prior studies on patients' use of mHealth apps have focused on patient acceptance and initial use of these apps [106-115], only a few studies have focused on the continuous use of mHealth services [127-130]. Some of these continuous use studies only examine the mHealth services for general healthcare, such as appointment and health consultation, instead of patient self-management of chronic conditions [127, 128, 130]. Cho develops and tests a model to explain the mechanism that determines the continuous use intention of mHealth services. He finds that continuous use intention is influenced by confirmation of the primary expectation of mHealth apps but does not specify the content of the expectation [130]. Lee et al. find that patients' intention to continuously use mHealth service is closely associated with their regular use of self-monitoring function; however, they do not further explore the relationship between these two constructs [129].

To date, there has been little theoretical research on factors influencing patients' continuous use of mHealth services to support their self-management of chronic conditions. To fill this gap, this research aims (1) to identify influencing factors and develop a predictive model to explain their relationships with patients' continuous use of mHealth services to support their self-management of chronic conditions; (2) to develop and validate a questionnaire survey instrument that empirically tests and theorises the model; and (3) to examine the associations among the variables and their relative impact on continuous use of a mHealth app. The theoretical model is tested in the context of hypertension self-management.

6.1.2 Theoretical Foundation

The constructs of the proposed model were drawn from the information systems (IS) continuance model [278] and IS success model [279]. Inspired by Oliver's Expectation Confirmation Theory [280], Bhattacherjee proposed that IS users' continuous use intention is similar to their repurchase decision-making [278]. They compare the benefits acquired from using an IS product or service with the prior expectation to decide the level of satisfaction with it. The comparison result, i.e. confirmation, becomes their reference for continuous use. This theory is known as IS continuance model. In this model, perceived usefulness and user satisfaction are considered crucial factors influencing continuous use intention and is associated with confirmation, thus being deemed as intermediate variables. However, the content of the confirmation is not clearly defined in this model, which makes it difficult to assess which factors determine the continuous use intention.

In their famous IS success model, Delone and McLean propose that three factors, information quality, system quality and service quality, determine use intention and satisfaction, and use intention and satisfaction predict IS success [279]. This theory has been widely adopted in studies that evaluate IS success [281, 282]. According to a published mobile technology acceptance model, usefulness predicts use intention [106]. Therefore, we posit that information quality, system quality and service quality may affect the perceived usefulness and user satisfaction of mHealth services to support patient self-management of chronic conditions.

6.1.3 Research Hypotheses

Information quality, System quality, Service quality and Perceived usefulness

Information quality refers to the quality of content that the mobile service provides. Its attributes include relevance, timeliness of update and easiness to understand [279, 283]. Perceived usefulness refers to a user's ex-post expectations and beliefs about the effectiveness and benefits of using a mHealth app from his/her experience [33]. Information quality is one of the critical determinants for IS success because the acquisition of information is the primary purpose for users to use an IS. Alsabawy et al. find that low-quality information provided by an e-learning system may mislead the users and consequently changing their perception of its usefulness [33]. System quality refers to the overall performance of a mHealth app as perceived by the users [279, 283]. It measures the technical success of a mHealth system. As an IS is the carrier of information, its quality is the prerequisite for ensuring that users can easily obtain the information they need. For example, if the functions of an IS are too complex and difficult to use, users may not invest time and energy to learn and use the system, which may weaken users' perception of the usefulness of the system [281]. Service quality refers to the support that a mHealth app user can receive from the support personnel and technical team who administers the system [279, 283]. The attributes include dependability, availability and empathy of the support staff. Dou et al. find that a good doctor-patient relationship is one of the prerequisites for patients to think that a mHealth service is useful to them [106]. For example, they think the mHealth service is useful only if they know the healthcare provider can help them solve problems through the app. Wu also find that high-quality service can increase the user's perceived usefulness of an online healthcare community [282]. Watts et al. suggest that assessment of the relationships between these IS factors needs to consider the context of IS use [284]. Therefore, it is posited that:

> *Hypothesis 1(a): Information quality is positively associated with patients' perceived usefulness of mHealth services.*
>
> *Hypothesis 1(b): System quality is positively associated with patients' perceived usefulness of mHealth services.*
>
> *Hypothesis 1(c): Service quality is positively associated with patients' perceived usefulness of mHealth services.*

Information quality, System quality, Service quality and User satisfaction

User satisfaction refers to a users' emotional or psychological state about the use of a system [279]. DeLone and McLean posit that system quality, information quality and service quality predict user satisfaction [279]. For example, patients are dissatisfied with irrelevant information in the app, such as overwhelming advertisements [128]. Users prefer a clean and simple interface and an easy-to-understand navigation menu. Zheng et al. suggest if the service provided by an IS does not provide the expected reliability or consistency, satisfaction with the IS will decrease. Consequently, it is posited that:

> *Hypothesis 2(a): Information quality is positively associated with user satisfaction of mHealth services.*

> *Hypothesis 2(b): System quality is positively associated with user satisfaction of mHealth services.*

> *Hypothesis 2(c): Service quality is positively associated with user satisfaction of mHealth services.*

Perceived usefulness, User satisfaction, Perceived health status, and Continuous use intention

Bhattacherjee suggests that perceived usefulness predicts user satisfaction [278] due to a likely positive emotional response derived from improvement in work efficiency and job performance by using the IS [285]. With this understanding, Kim and Lee focus on investigating the usefulness of their robot services to improve user satisfaction [286]. Likewise, if patients believe that using a mHealth app can help them control hypertension, they should also be satisfied with the app. Therefore, it is posited that:

> *Hypothesis 3: Perceived usefulness is positively associated with user satisfaction.*

Perceived health status refers to an individual's assessment of his/her health condition [287]. It reflects the physiological, behavioural, social, and psychological conditions that a person experience, which can be difficult to capture by other objective indicators [288]. Song et al. find that many patients reduce usage frequency or even stop using the mHealth service once their blood pressure is under control [289]. However, they will resume use once the blood pressure rises again.

Bhattacherjee suggests that perceived usefulness and user satisfaction will positively predict continuous use intention [278]. Vaghhefi and Tulu interviewed 17 people who used different apps to support their lifestyle changes, i.e., promoting physical activity and mindfulness [128]. The comparison of user perceptions two weeks before and after app usage suggests that user experience and perceived health goals are two factors influencing these people's continuous use intention. Therefore, it is posited that:

> *Hypothesis 4 (a): Perceived health status is negatively associated with continuous use intention of mHealth services.*
>
> *Hypothesis 4 (b): Perceived usefulness is positively associated with continuous use intention of mHealth services.*
>
> *Hypothesis 4 (c): User satisfaction is positively associated with continuous use intention of mHealth services.*

6.1.4 The Proposed Theoretical Model

The proposed continuous use model of mHealth services to support self-management of chronic conditions includes seven variables (see Figure 6-1). Four of them are independent variables: information quality, system quality, service quality, and perceived health status. Continuous use intention is the dependent variable. The rest two are mediators: perceived usefulness and user satisfaction.

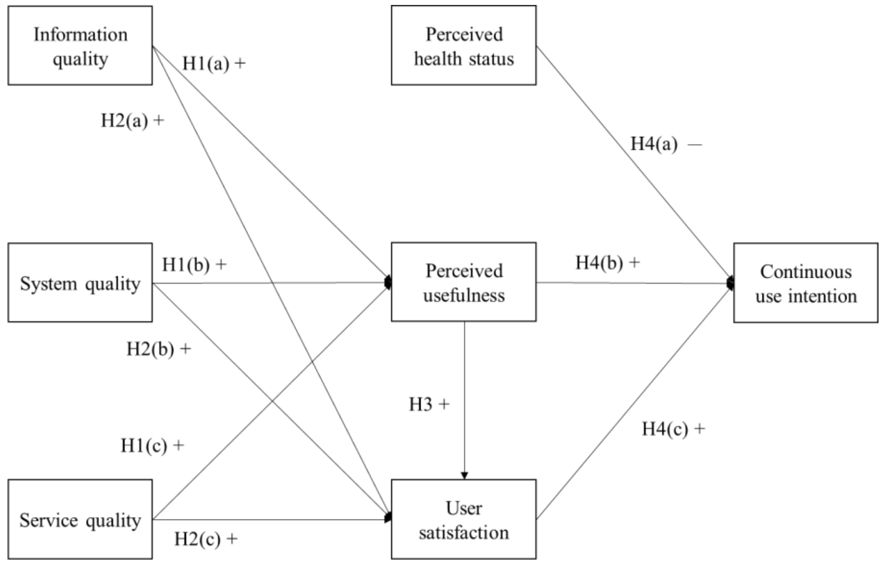

Figure 6-1 The proposed research model

6.2 Methods

6.2.1 Ethics Approval

This study was approved by the Human Research Ethics Committee of the General Hospital of Ningxia Medical University, China (Registration number: 2018-325).

6.2.2 Study Setting and mHealth Service

To improve patient hypertension management and population health, an international tripartite collaborative research program has been piloted. The mHealth service entitled "Blood Pressure Assistant" was developed by the Biomedical Informatics Laboratory at Zhejiang University to support outpatients to self-manage hypertension.

The mHealth service included an app for the patients to use and a Web-based portal for healthcare providers, including clinicians and certified health managers, to communicate with the patients. The functions of the app included (1) digital forms to record vital signs, i.e. blood pressure, heart rate, weight, and self-management behaviours, i.e. medication, exercise, and food; (2) health education materials; (3) reminders for self-management; (4) reports on daily/monthly statistical trend of vital signs and self-management performance; and (5) feedback about the BP level, being normal or not. The functions of the Web-based portal included (1) statistical results and visualisation charts of data recorded by patients; (2) abnormal detection alerts; and (3) patient classification and follow-up tracking reminders.

The mHealth service was implemented in the Department of Cardiology, General Hospital of Ningxia Medical University, China, in November 2015. The effectiveness of this service was evaluated in a clinical trial (Registration number: ChiCTR1900026437). The trial participants were hypertensive outpatients of the hospital and were provided with a one-hour face-to-face training before using the app. The training included the significance and methods of hypertension self-management, the way to install and use the app, and tips to solve common usage problems.

6.2.3 Questionnaire Survey Development and Data Collection

A five-point Likert Scale self-administered questionnaire was developed in 2017 to collect data to measure the seven latent variables (see Table 6-1) and testing the relationships among them. The questionnaire consisted of 17 questions, and all were adopted from the previously validated studies and modified to fit with our study context. Although each latent construct is best measured by at least three items [152], in balancing rigour with avoiding survey fatigue for satisfactory response rates [290]; we only used two items to measure five constructs in reference to the recommendation of the previous literature [106, 130, 281]. Each question was anchored between 1- 'strongly disagree' and 5- 'strongly agree'. The measurement items were translated into Chinese by one researcher, then discussed and validated by a panel of nine bilingual experts, including four clinicians, three medical informatics experts, one certified health manager, and one IS expert. One researcher then back-translated the instrument into English to confirm the accuracy and quality of the Chinese translation.

Table 6-1 Questionnaire constructs and their measurement items

Construct	Item code	Item description (references)
Information quality	*IQ1*	*Information provided by the Blood Pressure Assistant is relevant for my needs* ***[279, 281, 283]****.*
	IQ2	*Information provided by the Blood Pressure Assistant is sufficient enough for my needs* ***[279, 283]****.*
	IQ3	*Information provided by the Blood Pressure Assistant has been updated timely* ***[279, 283]****.*
System quality	*SysQ1*	*The Blood Pressure Assistant is easy to learn* ***[281]****.*
	SysQ2	*The Blood Pressure Assistant is easy to use* ***[279, 281]****.*
Service quality	*SerQ1*	*The health manager can resolve problems which I encountered when using the Blood Pressure Assistant* ***[279]****.*
	SerQ2	*The health manager gives me individual guidance in the follow-up phone calls* ***[279, 283]****.*
Perceived usefulness	*PU1*	*The Blood Pressure Assistant is of benefit to me [130].*
	PU2	*Overall, using the Blood Pressure Assistant is advantageous to my hypertension management .*
User satisfaction	*US1*	*I am contented with my use of Blood Pressure Assistant* ***[278, 291, 292]****.*
	US2	*I am satisfied with my use of Blood Pressure Assistant* ***[278, 281, 291, 292]****.*
Perceived health status	*PHS1*	*Currently, my blood pressure is back to normal* ***[293]****.*
	PHS2	*Currently, my blood pressure is under control* ***[293, 294]****.*
	PHS3	*Currently, I don't worry about my health [106].*
Continuous use intention	*CUI1*	*I intend to continue using the Blood Pressure Assistant rather than discontinue its use* ***[278, 291]****.*
	CUI2	*If I could, I would like to discontinue my use of the Blood Pressure Assistant (reverse coded)* ***[278]****.*

BP: Blood pressure

The questionnaire survey was then built into the mHealth app as a special functional module for the trial participants to complete. A participant information sheet was placed at the beginning of the questionnaire to inform them about the purpose of the survey, the voluntary nature of completing it, and the confidentiality and anonymity of their responses for any derived research publications. The participants could click a checkbox to express their consent. Some participants returned the completed questionnaire without clicking this checkbox, and this was treated as implied consent.

The questionnaire responses were extracted from the app database in March 2020 for analysis. The patients' demographic information, i.e. age, gender, and education level, was extracted from the database of the Web-based portal.

6.2.4 Data Analysis

The research model was tested by the partial least square structural equation modelling (PLS-SEM) using the software program SmartPLS (Version 3.0) [152, 153]. The PLS-SEM is commonly used to model the dynamic relationships between antecedent variables and dependent variables, thereby addressing the limitation of the multiple regression model with a relatively fixed relationship between variables and multicollinearity issues [295]. Moreover, the average number of latent variables in PLS-SEM is 7.94, which is much higher than 4.70 in covariance-based SEM [153]. Therefore, PLS-SEM is more conducive to solving more complex models. In addition, compared with the covariance-based SEM, PLS-SEM has a high level of statistical power even when the sample size is relatively small [296]. This is practical for studies that have difficulties in recruiting research subjects, especially for those which are inherently complex and sensitive, like this one.

The measurement model was tested by assessing reliability and validity [152, 297]. For reflective constructs, the indicator reliability was assessed by the indicator loadings and collinearity statistics, i.e. outer variance inflation factor (VIF) values. The construct reliability was assessed by Cronbach's alpha and composite reliability. The convergent validity was assessed by the average variance extracted (AVE). The discriminant validity was assessed by the Fornell-Larcker criterion, cross-loading, and the Heterotrait-monotrait value [152, 298].

For formative constructs, reliability was an irrelevant assessment criterion [297]. The indicator validity was assessed by the indicator weights and VIF. The discriminate validity was assessed by inter-construct correlations.

The structural model was tested by path coefficients (β), variance explained (R^2), effect size (f^2), and blindfolding-based cross-validated redundancy measure (Q^2). Path coefficients (β) measured the direct effect of a variable assumed to be a cause on another variable assumed to be an effect [299]—positive β value referred to a positive association, and vice versa. Variance explained (R^2) referred to in-sample predictive power, which measured a model's explanatory power [300, 301]. Effect size (f^2) explained the changes before and after an exogenous construct is included and excluded from the model [302]. The f^2 values of 0.02, 0.15, and 0.35 were considered as small, medium and large effects, respectively. The Q^2 value was used to assess the PLS path model's predictive accuracy [303, 304].

6.3 Results

6.3.1 Survey Participant Characteristics

A total of 142 participants completed the questionnaire survey. Four of them gave the same answer to all the questions. Another eight provided the same answer to Questions 16 and 17, which were opposite to each other in nature. These responses were considered invalid responses and were excluded from further data analysis. Therefore, a total of 129 responses were used in the statistical analysis. There are two requirements regarding the sample size. First, the ratio of the sample size to the number of parameters should be greater than 5:1 [305]; second, the sample size should be greater than ten times the largest number of either the formative items used to measure a single construct or the largest number of paths the latent variable has in the model [152, 153, 295]. In this study, the number of parameters is seven; the number of formative items is three, and the number of paths the latent variable has is ten. Therefore, our sample size of 129 responses surpassed the two threshold requirements.

The participants' age ranged from 34 to 79 years, with a median of 53 years. There were two times more males than females who participated in the survey. Seventy per cent of the respondents were in the age group of 40 to 59 years, 63% were in the workforce, and 75% had an educational level of high school or above (see Table 6-2).

Table 6-2 Demographics of the participants

Characteristics	n (%)
Gender	
Male	**98 (76.0)**
Female	**31 (24.0)**
Age	
<40	**7 (5.4)**
40-49	**48 (37.2)**
50-59	**42 (32.6)**
60-69	**23 (17.8)**
>=70	**9 (7.0)**
Employment status	
Employed	**66 (51.2)**
Self-employed	**15 (11.6)**
Unemployed	**7 (5.4)**
Retired	**29 (22.5)**
No response	**12 (9.3)**
Educational level	
Primary and middle school	**22 (17.1)**
High school	**25 (19.4)**
University/College/Graduate	**69 (53.5)**
Postgraduate	**4 (3.1)**
No response	**9 (6.9)**

6.3.2 Descriptive Statistics of the Constructs

The mean scores of all latent variables were positive, i.e. close to or over four in the five-point Likert Scale (Table 6-3). In particular, the first item to measure the continuous use intention, "I intend to continue using the Blood Pressure Assistant rather than discontinue its use" reached a high mean score of 4.519, suggesting that the participants had high intention to continue to use the mHealth service.

6.3.3 Measurement Model Validation

For the reflective constructs, i.e. perceived usefulness, user satisfaction, perceived health status, and continuous use intention, each item was loaded above the threshold value of 0.708 on its respective construct and was significant at $P < .050$ (see Table 6-3). All VIF values were below 3, indicating some correlation but not enough to be overly concerned about [306]. These confirmed the indicator reliability. All Cronbach's alpha and composite reliability values were above .7, which confirmed the construct reliability. All AVE values were above .5, with their square root presented in the diagonal (see Table 6-4). The AVE of each construct were greater than its squared correlations with other constructs, confirming the convergent validity. The cross-loadings of each indicator on other constructs were lower than that on its designated construct, and each indicator loaded highest on its own construct. All the Heterotrait-monotrait values were below 0.9. These confirmed the discriminant validity of the constructs [307]. For the formative constructs, i.e. information quality, system quality and service quality, each item was weighted above the threshold value of .2 on its respective construct and was significant at $P < .050$. All the VIF values were below 3, confirming the indicator validity [306]. The correlations between the formative and all the other constructs were less than .7, confirming the discriminant validity.

Table 6-3 Descriptive statistics of the construct, internal reliability and convergent validity.

Construct	**Scale**	**Item code**	**Mean (Standard deviation)**	**Standardised loading/weight**	**VIF (outer)**	**CA**	**CR**	**AVE**
Information quality	Formative	IQ1	4.31 (0.745)	0.292	1.632	N/A	N/A	0
		IQ2	4.318 (0.757)	0.555	1.513			
		IQ3	3.953 (0.879)	0.395	1.284			
System quality	Formative	SysQ1	4.519 (0.572)	0.428	2.032	N/A	N/A	0
		SysQ2	4.481 (0.624)	0.649	2.032			
Service quality	Formative	SerQ1	4.271 (0.745)	0.369	2.284	N/A	N/A	0
		SerQ2	4.085 (0.778)	0.693	2.284			
Perceived usefulness	Reflective	PU1	4.202 (0.73)	0.917	2.006	0.829	0.921	0.854
		PU2	4.38 (0.587)	0.931	2.006			
User satisfaction	Reflective	US1	4.504 (0.599)	0.900	1.725	0.787	0.903	0.824
		US2	4.488 (0.544)	0.915	1.725			
Perceived health status	Reflective	PHS1	4.101 (0.796)	0.828	1.759	0.771	0.867	0.684
		PHS2	4.031 (0.787)	0.833	1.71			
		PHS3	4.225 (0.707)	0.821	1.415			
Continuous use intention	Reflective	CUI1	4.519 (0.558)	0.946	1.417	0.703	0.860	0.756
		CUI2	4.116 (0.85)	0.786	1.417			

VIF: variance inflation factor; CR: composite reliability; AVE: average variance extracted

Table 6-4 Discriminant validity.

	1	2	3	4	5	6	7
1. Continuous use intention	**0.87**	—	—	—	—	—	—
2. Information quality	0.489	—	—	—	—	—	—
3. Perceived health status	0.466	0.43	**0.827**	—	—	—	—
4. Perceived usefulness	0.578	0.618	0.458	**0.924**	—	—	—
5. Service quality	0.39	0.525	0.321	0.496	—	—	—
6. System quality	0.452	0.572	0.293	0.699	0.367	—	—
7. Use satisfaction	0.574	0.514	0.513	0.714	0.426	0.478	**0.908**

The values presented in bold on the diagonal are the average variance extracted values.

6.3.4 Structural Model and Hypothesis Testing

For the path coefficient (β) and variance explained (R^2), our results showed that information quality, system quality and service quality were all positively associated with perceived usefulness. Perceived usefulness and user satisfaction were positively associated with continuous use intention. Perceived usefulness was positively associated with user satisfaction. However, opposite to the original hypothesis, perceived health status was also positively associated with continuous use intention. Therefore, hypotheses 1(a), 1(b), 1(c), 3, 4 (b) and 4(c) were confirmed but hypotheses 2(a), 2 (b), 2 (c) and 4 (a) were not confirmed (see Table 6-5, Figure 6-2).

The effects of service quality on perceived usefulness and of perceived usefulness on user satisfaction were both large, while other paths showed small effects. The Q^2 values for all the three endogenous constructs were positive, i.e. perceived usefulness (.400), user satisfaction (.337) and continuous use intention (.144), which confirmed the model's predictive accuracy.

Table 6-5 Structural model validation and hypothesis test results

Path	Standard error	T statistics	P-value	Effect size (f^2)	Hypothesis test
H1(a): IQ→PU	.083	2.839	.005	Small (.074)	Confirmed
H1(b): SysQ→PU	.084	2.293	.022	Small (.064)	Confirmed
H1(c): SerQ→PU	.089	5.525	.000	Large (.391)	Confirmed
H2(a): IQ→US	.094	1.193	.233	None (.014)	Not confirmed
H2(b): SysQ→US	.085	0.761	.447	None (.006)	Not confirmed
H2(c): SerQ→US	.087	0.852	.394	None (.005)	Not confirmed
H3: PU→US	.100	6.632	.000	Large (.384)	Confirmed
H4(a): PHS→CUI	.092	2.121	.034	Small (.047)	Not confirmed
H4(b): PU→CUI	.107	2.879	.004	Small (.077)	Confirmed
H4(c): US→CUI	.122	2.082	.037	Small (.049)	Confirmed

IQ: Information quality; SysQ: System quality; SerQ: Service quality; PU: Perceived usefulness; US: User satisfaction; PHS: Perceived health status; CUI: Continuous use intention

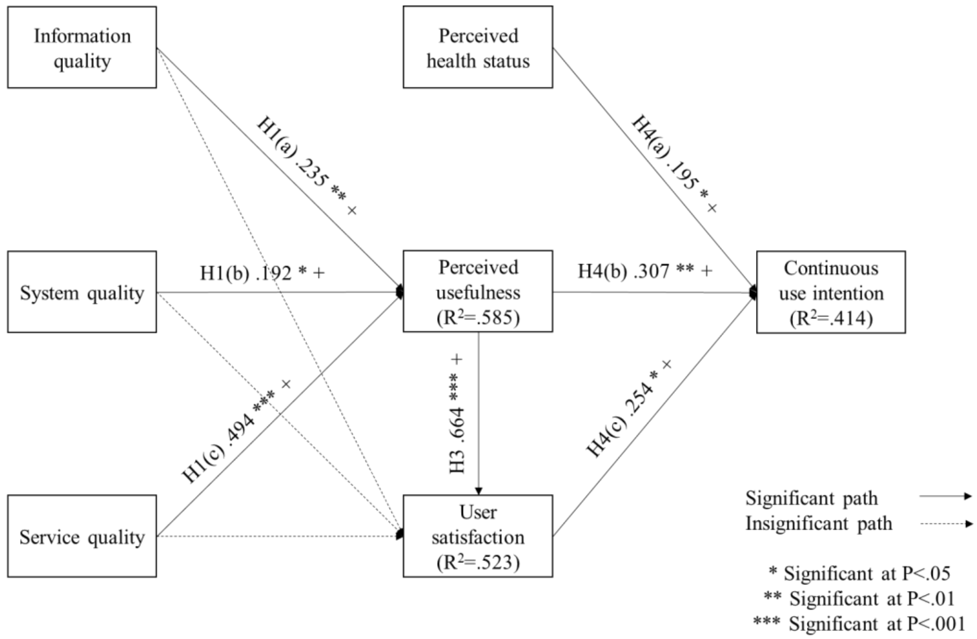

Figure 6-2 The validated theoretical model

6.4 Discussion

6.4.1 Principal Results

This empirical study proposes a theoretical model to predict and explain patients' intention to continue using the mHealth service to support self-management of chronic conditions (see Figure 6-2). The model is derived from a hybrid model synthesised from IS continuance model and IS success model [278, 279]. The statistical assessment confirmes the reliability and validity of its measurement scale (see Tables 6-3 and 6-4). Six out of ten original hypotheses about the relationships among seven variables are confirmed (see Table 6-5). Information quality, system quality and service quality have a significant positive influence on perceived usefulness, but not on user satisfaction. Perceived usefulness has a significant positive influence on user satisfaction. Perceived usefulness and user satisfaction both have positive influences on participants' intention to continue using the mHealth services.

Contrary to the original hypothesis of a negative association, the patients' perceived health status is positively associated with their continuous use intention. This may be explained by the motivation effect of positive reward stemmed from the decreased blood pressure, which can directly motivate patients to form a virtuous cycle in their self-management of chronic conditions, i.e. the better result in blood pressure control, the more active a patient will use the app. Another possible reason is that frequent use of self-monitoring mechanism, i.e., entering and monitoring own health data, has become a daily routine or habit. Thus it is no longer influenced by intention, which only impacts voluntary use [308]. Lee et al. find that after introducing the self-monitoring function, the negative slope of the downward trend in mHealth service usage has been alleviated in patients for self-management of their general health, which supports the long-term positive effect of self-monitoring for chronic conditions [129].

However, according to Health Belief Model [309], which defines the key factors that influence health behaviours, one of the most key factors is the perceived severity, i.e. belief of the consequence of the conditions. That is, once a patient's blood pressure is controlled, the person's perceived health status is improved, and the perceived severity is relieved; therefore, the use intention will decrease. We consider the paradox may be moderated by health literacy [108, 310]. For patients with high health literacy, awareness of the negative consequences of not using the app, coupled with the motivating effect brought by the perceived usefulness, will motivate them to use the app continuously. Conversely, for patients with low health literacy, due to their lack of understanding of the negative effect of discontinued use, they may not intend to use the app after a period of time or when the blood pressure is controlled. This is similar to the findings of Guo et al. that a patient's health consciousness has a significant, positive impact on the relationship between social media influence and continuous use intention [127]. Therefore, health literacy could be a moderator for the relationship between perceived health status and continued use intention, which can be further tested in the follow-up study.

The results also support the importance of providing feedback to patients about their health status that is reflected by the vital signs they uploaded in mHealth services [289]. Awareness of their own health status, particularly if the disease is deteriorating, will drive them to formulate an intention to continuously use the mHealth services. Conversely, when health status is improving, patients might feel bored by repeatedly entering and uploading data day after day through the mHealth app, as found by Biduski et al. [311]. Without the feedback and awareness about their own health status, patients would assume they are in good health and gradually lose intention to use the services.

6.4.2 Contributions

Theoretical Contribution

Our theoretical model is derived from two classical IS models. The IS continuance model emphasises the impact of expectation on perceived usefulness and user satisfaction based on the expectation-confirmation theory [278, 280]. However, it does not clearly indicate which factors of the expectations are confirmed. The IS success model clarifies and supplements the three factors of the expectation: information quality, system quality and service quality [279].

As hypothesised, our study confirms the cascading effects of the three antecedent variables, i.e., information quality, system quality, and service quality, on a patient's continuous use intention through the intermittent variables, i.e. perceived usefulness and user satisfaction. This is in line with Wu's findings that information quality and service quality have a significant positive impact on perceived usefulness [282]. In our study, service quality plays a more important role than information quality and system quality, which may indicate the importance of healthcare provider ongoing support for patients to continuously use the mHealth app, as found by the previous study in the same population that relationship with the healthcare provider is one of the determinants for the patient's intention to use the same app [106]. The service in Wu's study is the online health community [282]. Patients usually communicate with their doctors and seek relevant information through the online community. Our service provides patients with a disease-focused intervention specifically for the management of hypertension. In addition to obtaining information, the patients also require ongoing support provided by a health manager, which is an important component of service. This is also reflected in the positive evaluation of patients in Questions 6 and 7, i.e. "The health manager can resolve problems which I encountered when using the Blood Pressure Assistant" (4.3/5), and "The health manager gives me individual guidance in the follow-up phone calls "(4.1/5). The services provided by the health manager include guidance and assurance on self-management when abnormal blood pressure is detected. They would call them or their family to discuss and modify the management plan. These interactions gives patients the comfort that they have the full attention and receive high-quality services from their healthcare providers. These enhance their rapport with healthcare providers and trust and recognition of service quality so that patients can perceive the usefulness of mHealth and generate the intention of continuous use. Our finding confirms the vital role the healthcare providers play in keeping patients using the mHealth service continuously.

The finding that system quality has less influence on perceived usefulness in comparison with information and service quality may be explained by the complexity and persistent effort required for the management of chronic conditions [312]. Unlike the use of other systems, patients are more concerned about whether the service and information provided by the app can help them control the disease. This may also explain why user satisfaction is not directly affected by information quality, service quality and system quality, but indirectly through perceived usefulness.

Practical Contribution

Although the rapid development of mHealth services and the initial acceptance by patients have brought new opportunities for the management of chronic conditions, due to the lasting nature of these conditions and the long-term requirements for behaviour modification, only patients who continue to use the mHealth service can benefit from such services. Our research results show that the three independent factors, information quality, system quality and service quality, determine patient's intention to continuous use mHealth services through the mediation of perceived usefulness and user satisfaction. In the context of this study, service quality is the assistance and feedback of healthcare providers; information quality is the provision of reliable and relevant information; system quality is an easy-to-learn and easy-to-operate system that is essential for patients' continuous use of mHealth service. Therefore, in order to successfully introduce mHealth innovation into patient self-management of chronic conditions, it is necessary to focus on improving the responsibility and ability of healthcare providers and continue to provide and update educational information for patients to improve their awareness of the disease threat and effective self-management methods. These strategies will further enable patients to understand the usefulness of mHealth services and satisfy with using the services continuously to manage their chronic conditions.

6.4.3 Limitations and Future Work

The first limitation of this study is the limited geographical and social coverage of the study population, which is limited to an under-developed area in China. The sample size is relatively small, only 129 patients, despite reaching the threshold for theoretical sampling. The mHealth app is purposely built to test the feasibility of hypertension control using an app; thus, its usability may not represent all mHealth apps for any type of chronic conditions. Thus, the findings should be cautiously generalised. Second, the latent variables were selected based on the group's previous research experience and literature review; other factors may also need to be captured in the model that we tested, e.g. health literacy. Third, as a trade-off of avoiding survey fatigue and improving response rates [290], many constructs were measured by two items instead of three items suggested by [152] which was suboptimal from the perspective of measurement theory. In addition, since the questionnaire is answered voluntarily by the users of the mHealth service, the results cannot avoid the positive bias in sampling, which has eliminated the non-users. In addition, although the analysis is rigorous, this study did not include control or moderating variables, such as patient characteristics, into the structural model for the sake of meeting the threshold number of measures in structural equation modelling. Future research could also consider other independent variables that may influence perceived usefulness, user satisfaction or continuous use intention, especially those related to health contexts, such as perceived risk and patient-doctor relationship [106, 108]. In addition, follow-up research can be extended to study the actual continuous use and the determinants besides the continuous use intention. Future research also needs to be conducted as an empirical field study on the long-term effects of the mHealth services in the natural setting to derive generalisable insight for improving the practice of implementing mHealth services.

6.5 Conclusions

This study develops a model and questionnaire survey instrument to measure the success of patients' continuous use of mHealth services to support their self-management of chronic conditions. It finds that patients' intention to continue to use a mHealth service to support their self-management of chronic conditions is influenced by information quality, system quality and service quality through the mediation of perceived usefulness and user satisfaction. The patients' perceived health status also has a significant, positive influence on their continuous use intention. The validated model and measurement scale are useful for the routine evaluation of patients' continuous use of mHealth services, which is also important for evaluating the operational effect of the mHealth program. The research model and questionnaire survey instrument developed can be used for routine identification of the areas of mHealth management provided to the patients that support their use of the mHealth services that need improvement, i.e., information quality, mobile app usability, and technical and healthcare provider services. The findings also enrich the body of knowledge of mHealth continuous use to support patient self-management of chronic conditions. Future research can apply the model and questionnaire survey instrument to other types of mHealth services.

Summary

This chapter adds a time dimension to understand mHealth services from Donabedian's healthcare quality assessment model and addressed Research Question 3. It investigated the determinants and developed a predictive model to explain their relationship with patients' intention to continue to use mHealth services to support their self-management of chronic conditions. The research findings are acquired via a cross-sectional questionnaire survey to empirical testing of the model in 121 hypertensive patients who used the same mHealth service as that reported in Chapter 5. It is found that the patients' continuous use intention is influenced by information quality, system quality and service quality through the mediation of perceived usefulness and user satisfaction. Patients' perceived health status also has a significant, positive influence on their continuous use intention. The validated model and questionnaire survey instrument are useful for the routine evaluation of patients' continuous use of mHealth services, for evaluating the operational effect of the mHealth program, and for routine identification of the performance of mHealth services in terms of information quality, mobile app usability, and technical and healthcare provider services. The findings also enrich the body of knowledge of mHealth continuous use to support patient self-management of chronic conditions, which is consistent with the sustainable development requirements of mHealth services [46, 183].

Chapter 7

A Clinician-Led, Experience-Based Co-Design Approach for Developing mHealth Services to Support Patient Self-Management of Chronic Conditions: Development and a Design Case for Obesity Control

Forward

Chapters 3-6 explored the mechanisms for mHealth services to support patient self-management of chronic conditions. The major findings are summarised in Figure 7-1.

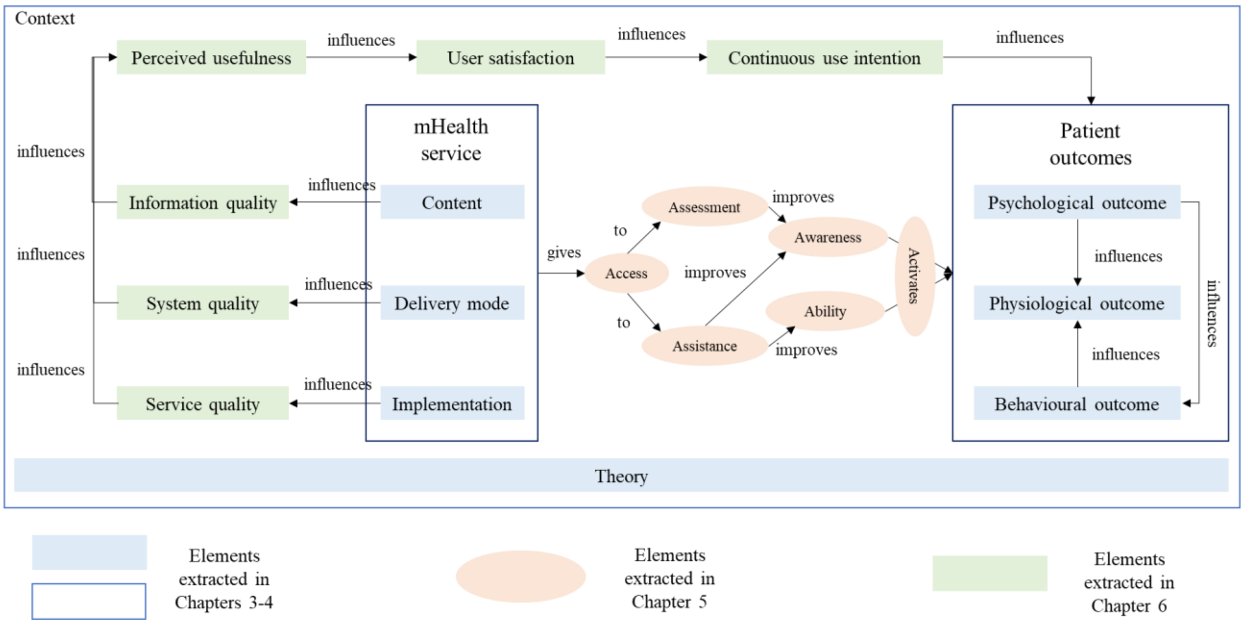

Figure 7-1 A comprehensive framework to support patient self-management of chronic conditions

The five structural components of mHealth services are context, theory, content, delivery mode, and implementation. The context and theory set up the environment and foundation for the use of the mHealth service. The content, delivery mode and implementation procedures co-shape the mHealth service. Mobile health service gives patients low-threshold access to health assessment and healthcare assistance. Reviewing the vital signs and assessment results of self-management behaviours can increase patient awareness of the effectiveness/or lack of it in self-management. Mobile health services also afford assistance, including health education and reminders to help patients improve their ability and "cues to action" for self-management of chronic conditions. The improved awareness and ability activate self-management behaviours and help to improve physiological outcomes, i.e., well-being. As successful self-management of chronic conditions is contingent upon long-term patient engagement, Chapter 6 reported an empirical study to understand the factors impacting continuous patient use of mHealth services. This chapter reports an action study in applying the knowledge and learning from the research reported in the chapters above in a novel project that designed a mHealth application. It took a clinician-led, co-design approach in multidisciplinary collaboration to improve the knowledge about patients' need for mHealth services. A design case is presented to illustrate our innovative approach to design a mHealth app that supports self-management of patients with obesity in their preparation for elective surgery in Australia.

This chapter is a reproduction in full of the paper "A clinician-led, experience-based co-design approach for developing mHealth services to support the patient self-management of chronic conditions: Development study and design case" authored by **Ting Song,** Ping Yu, Vida Bliokas, Yasmine Probst, Gregory E Peoples, Siyu Qian, Lauren Houston, Pascal Perez, Mehrdad Amirghasemi, Tingru Cui, Nadeesha Pathiraja Rathnayaka Hitige, and Natalie Anne Smith, and published in *JMIR mHealth and uHealth* 9, no.7 (2021): e20650.

The numbers of figures, tables, sub-headings and appendices have been re-numbered to keep the coherence of this thesis.

Abstract

Background: Despite the increasing use of mobile health (mHealth) services, such as mHealth apps or text-messaging services, to support patient self-management of chronic conditions, Many existent mHealth services fall short in lacking theoretical guidance. In addition, although often being the targeted audience for requirements acquisition at the initial mHealth app design stage, it is a common challenge for patients to fully conceptualise their needs for mHealth services that support them to self-manage chronic conditions.

Objective: This study proposes a novel co-design approach with the initial requirements for the mHealth services being proposed by the clinicians based on their experiences in guiding patients to self-manage chronic conditions. A design case is presented to illustrate our innovative approach to design a mHealth app that supports self-management of patients with obesity in their preparation for elective surgery.

Methods: A clinician-led, co-design approach was undertaken by a multidisciplinary team. The co-design approach consists of four cyclic phases: understanding user needs, identifying applicable underlying theory, integrating the theory into the prototype design, and evaluating and refining the prototype mHealth services by patients. Expert panel discussion, literature review, intervention mapping and patient focus group discussions were used in these four phases, respectively.

Results: In Stage 1, the expert panel proposed three common user needs: motivational need, educational need, and supportive need. In Stage 2, the team selected Social Cognitive Theory to guide the app design. In Stage 3, the team designed and developed the key functions of the mHealth app, including automatic push notifications, online resources, goal setting and monitoring, and interactive health-related exchanges that encourage physical activity, healthy eating, psychological preparation, and a positive outlook for elective surgery. Push notifications were designed in response to a patient's risk level as informed by the person's response to a baseline health survey. In Stage 4, the prototype mHealth app was used in further requirement capturing from patients in two focus group discussions. The prototype app provided the patients with the opportunity to interact with a living app, which facilitated them to voice their needs and envisage their desired functions of the mHealth app. The requirements gathered enabled the research team to further improve the design of the mHealth app.

Conclusions: This study reports an innovative co-design approach to leveraging the clinical experiences of the clinicians to produce the initial prototype app and the approach taken that allowed patients to effectively voice their needs and expectations for the mHealth app in a focus group discussion. This approach can be generalised to the design of any mHealth services that aim to support patient self-management of chronic conditions.

Trial Registration: Australian New Zealand Clinical Trials Registry: ACTRN379452

7.1 Introduction

7.1.1 Background

With the ubiquity of smartphones and the Internet, there has been increasing use of mobile health (mHealth) services in healthcare systems worldwide to support patient self-management of chronic conditions, such as hypertension, diabetes and obesity [131, 133, 142, 313]. This has become even more salient since 2020 as demand for and use of telemedicine services has increased due to the COVID-19 pandemic [313, 314]. The use of mobile apps to collect various patient data, i.e., ecological momentary assessment or experience sampling, has gained momentum for supporting self-monitoring, developing self-awareness and promoting behavioural change [85, 315].

The design techniques of mHealth services have also been continuously evolving, from the traditional system design methods focusing on their appearance, functionality and values to interactive design methods focusing on the way users interact with the mHealth services. Common interactive design methods include user-centred design [141, 145, 316], activity-centred design [317], and goal-directed design [318], focusing on the object, process, and outcome of product use, respectively. In order to increase user engagement and meet the needs of multidisciplinary collaboration, the development team can also invite all stakeholders, such as domain experts, users, and researchers, to participate in the design and development, known as co-design [143, 144]. This is especially relevant when addressing specific diseases or improving physical and mental well-being.

Behavioural change theories and models, such as Social Cognitive Theory (SCT) [263] and Health Belief Model (HBM) [221], drawn from psychology and sociology [217, 319], focus on predicting and explaining human behaviour and the wide range of factors that affect these behaviours such as emotions, habits and daily routines. They provide a roadmap for scientific research and practice [320] and are useful in guiding the implementation of successful mHealth services [321]. Mobile health services based on sound behavioural change theories are more likely to lead to positive changes in health behaviour [140, 322], i.e., to lead to successful changes in physical activity and healthy eating [323, 324]. Behavioural change techniques include monitoring, intention building, goal setting and planning, progress reflecting and performance reporting [325, 326]. They can be implemented in more interactive and dynamic functionalities in mHealth apps to motivate patients [136].

Despite their increasing popularity, the reported effectiveness of mHealth services to support patient self-management of chronic conditions is mixed [131-135]. The frequency with which large numbers of such services enter the market, coupled with the limited time that professional clinicians have available, has inhibited clinician participation in mHealth app design or evaluation [133]. Heterogeneity in mHealth design and purpose also leads to different levels of app usage. For example, apps only being designed as data collection tools instead of comprehensive interventions might not lead to positive changes in health behaviour [136]. Similarly, merely providing health information on a regular basis is proven to be ineffective unless reinforcement and motivation are also provided [89, 137]. As mentioned above, inadequate application of behavioural change theory to guide the design and implementation of mHealth services also leads to unsatisfactory intervention effects [134, 138-140]. In addition, although often being the targeted audience for requirements acquisition at the initial mHealth app design stage, it is a common challenge for patients to fully conceptualise their needs for mHealth services that support them to self-manage chronic conditions [135]. These may lead to the ineffectiveness of the mHealth services [141-145].

7.1.2 Research Aim

In order to address the above limitations for the design of effective mHealth services that support patient self-management of chronic conditions, this study proposes a novel approach with the initial requirements for the mHealth services being proposed by the clinicians based on their experiences in guiding patients to self-manage chronic conditions. A co-design approach is taken in multidisciplinary collaboration to improve the knowledge about patients' need for mHealth services.

7.1.3 A Design Case of mHealth Services for Preoperative Obesity Management

Obesity has increasingly become a global public health challenge, with 5.9 million Australians (31.3%) having a body mass index over 30 kg/m^2 in 2017-18 [327]. Obesity can complicate procedures such as siting intravenous cannulae and inserting endotracheal tubes. It may affect weight-based decisions like ventilator settings or drug doses and can also make surgical access more difficult [328, 329]. Obesity is also a risk factor for short-term postoperative complications such as infection, deep venous thrombosis, poor wound healing, blood loss, respiratory problems and myocardial infarction [328, 330, 331]. In Australia, the average waiting time for elective surgery in public hospitals is 41 days [332]. Losing weight and improving preoperative fitness through lifestyle change during this period, known as prehabilitation, is gaining increasing attention [333, 334].

Common methods of prehabilitation include engagement in regular physical activities, dietary optimisation and psychological support [335, 336]. Current evidence suggests that higher preoperative fitness can lead to fewer last-minute cancellations, better postoperative outcomes and shorter patient waiting times [337-339]. However, many local healthcare systems do not have enough resources to help patients with obesity improve their preoperative fitness for surgery, even when the period between booking and performance of surgery can be up to 12 months. Moreover, dietary modifications and changes in physical activity are difficult to maintain [88, 340]. Therefore, innovative methods are needed to encourage and motivate patients with obesity to improve their physical fitness, dietary habits and mental well-being prior to elective surgery.

To date, using mHealth services to improve preoperative fitness is in its infancy [341, 342]. There are bariatric surgery specific apps available in app stores; however, there is no study reporting the use of behavioural theory to guide the development of mHealth services to deliver health and weight management coaching to patients with obesity before elective surgery [343, 344]. Considering there is still room for further research on embedding relevant behavioural theory within mHealth apps to improve effectiveness, a case is presented to illustrate our innovative approach to design a mHealth app that supports self-management of patients with obesity in their preparation for elective surgery.

7.2 Methods

A clinician lead, co-design approach was undertaken by a multidisciplinary team for designing the mHealth services to support patient self-management of chronic conditions. Experience-based co-design principle [345] and the guidelines for developing complex interventions to improve health and healthcare published by the UK Medical Research Council (MRC) [346] have been followed in our approach to the mHealth app design. Experience-based co-design claims all stakeholders, including researchers, developers, and service users, to participate in the design process and to develop a set of feasible service plans or care paths through gathering their experiences [345, 347]. The MRC framework defines a series of actions for intervention development [346]. Based on these references, we formulated four iterative phases for the prototype mHealth app design:

understanding user needs, identifying applicable underlying theories, integrating theory into the prototype design and development, and evaluating and refining the prototype mobile app (see Figure 7-2). Expert panel discussion, literature review, intervention mapping and focus group discussions were used in these four phases, respectively.

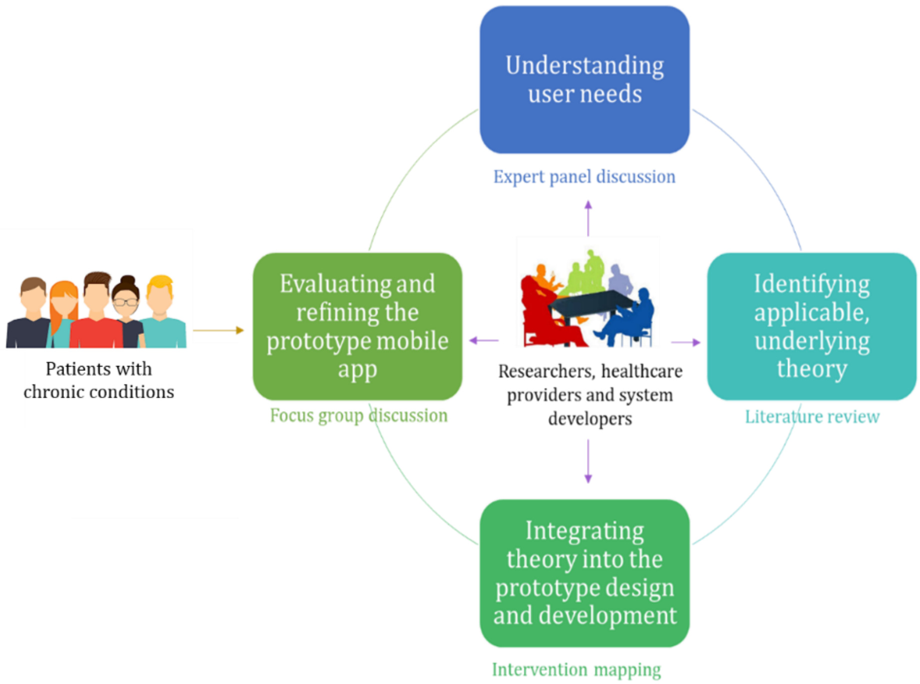

Figure 7-2 Stakeholders, procedures and methods of the intervention development (adapted from O'Cathain et al. [365])

7.2.1 Phase 1. Understanding User Needs

A multidisciplinary team of 12 experts, formed through the existing research collaborative network, conducted monthly panel discussions at the University of Wollongong, Australia, for eight months, to understand potential user needs. Eight team members hold a PhD, and four hold Master's or Bachelor's (with Honours) degrees as their highest qualification. Nine panel members had more than five years of research experience related to health sciences.

A clinical anesthetist (author NS), with 20-year clinical experience in Wollongong Hospital, described the issues relating to obesity, anesthesia and surgery, which provided information on user needs from a clinical perspective. She noted that the challenge of obesity is particularly problematic in the local area, the Illawarra and Shoalhaven Local Health District (ISLHD), New South Wales, Australia, in which the prevalence of obesity is higher than the national figure (36% compared to 28%) [159]. According to local audit data, one-third of patients scheduled for elective surgery waited more than three months between booking and operation, and about half of them gained weights while on the waiting list. In Wollongong Hospital, approximately 55% of the 6,000 patients who undergo elective surgery each year have obesity [348].

Together with an eHealth researcher (author PY), these authors proposed that a mHealth intervention could potentially address the needs of this population. An accredited clinical psychologist (author VB), accredited practising dietitian (author YP), and accredited exercise physiologist (author GP) provided specific input in their areas of expertise. Another seven researchers in health information systems (authors SQ, TC, LH, TS) and software engineering (authors PP, MA and NH) were also involved in designing the technical solution for delivering the intervention.

7.2.2 Phase 2. Identifying Applicable, Underlying Theory

After understanding the preliminary user needs, the researchers conducted a literature review to identify applicable underlying theories to guide the app design. A search of three interdisciplinary databases (Scopus, PubMed and PMC) was conducted, which allowed for the inclusion of peer-reviewed English-language journal articles. Terms, MeSH headings and their variants applied were "theory" or "model", "intervention" or "program", and "behavioural change". Empirical studies and systematic reviews that reported the explicit use of theory in guiding lifestyle-related behavioural change were included in the study. Studies that did not report the reason why or how the theory was used were excluded. The data was extracted into an Excel spreadsheet for constant comparison and analysis. The team then selected the most suitable theory to guide the prototype design for this study.

7.2.3 Phase 3. Integrating Theory into the Prototype Design and Development

After selecting SCT as the most applicable theory, our team used it as a framework to integrate the prototype design, following the intervention mapping protocol which is widely used for the development of theory-based health promotion programs [349]. We firstly listed all user needs based on their understanding of health issues, risk groups, behavioural and environmental determinants, and available resources. Secondly, we listed the constructs of the selected theory and the evidence-based intervention techniques used to guide the behavioural changes that fit the above intervention context. Thirdly, we mapped these intervention techniques into the app design to build different functional modules. Fourthly, we designed the system architecture, functional modules, user interface and database, and integrated these components into a coherent program, being a prototype mobile app, through several iterations. React Native, an open-source framework that uses JavaScript and React to develop native, iOS and Android mobile apps, was used in the development [350].

7.2.4 Phase 4. Evaluating and Refining the Prototype Mobile App

The prototype mobile app was pilot used by patients with obesity to gauge their perceptions about its usefulness and usability. The pilot trial was conducted in two focus group discussions of six people per group in November 2019. Participants were recruited via purposive sampling of patients with obesity who were undergoing weight-loss treatment at a hospital in the South-Western Sydney Local Health Service via existing networks. The inclusion criteria were patients who (1) were 18 years and over; (2) had a body mass index greater than or equal to 35kg/m^2; (3) were

English-speaking with self-elected adequate reading skills; and (4) provided informed consent to participate in the study. A clinic nurse initially discussed the project and sought verbal consent from each patient for participation in the focus group discussion. One week later, patients were sent a text message asking for confirmation of their verbal consent. Ethical approval for the study was obtained from the University of Wollongong and ISLHD Health and Medical Human Research Ethics Committee (2018/175; HREC/18/WGONG/64).

One researcher (author LH) with prior training in research theory and experience in conducting and observing qualitative research moderated the semi-structured focus group discussions. For each group, she gave a brief introduction to the participants and asked them to sign a written consent form. She then distributed three mobile phones and three mobile tablets with the app pre-installed to all participants and instructed them on its use. After time spent with the app, a semi-structured list of questions was deliberated in the group, discussing the relevant functions of the app (see Appendix C-1). The conversation continued until all of the relevant issues and opinions were openly raised and discussed, beyond answering the interview questions.

The focus group discussions were audio-recorded and transcribed verbatim. Three other researchers were present as observers and took notes to record non-verbal characteristics of the focus groups, such as gender. The total discussion time for each group was about one hour and 30 minutes.

The transcripts were analysed using a content analysis approach to capture patients' feedback [269]. Each original sentence was judged by two researchers independently to see if it contained a suggestion that would be useful for improving the app functionality. These suggestions were listed in point form and circulated to the expert team. The approved and feasible suggestions were discussed by the developers for further modification.

7.3 Results

7.3.1 Phase 1. Understanding User Needs

The expert panel discussion proposed three kinds of potential needs for patients with obesity to improve fitness before surgery: motivational needs, educational needs, and supportive needs.

Motivational needs

Many individuals find it difficult to maintain sufficient motivation to lose weight over time. Many have repeated failed experiences, often with initial weight loss followed by regaining weight, which can further decrease confidence and motivation [88, 351]. It is well recognised that supporting motivation is essential for sustainable behavioural change [46, 142, 234, 326].

Educational needs

Educating patients with obesity about the general health risks related to obesity remains important. Most have not considered risks that are specifically associated with anesthesia and surgery, and many do not realise that obesity in itself poses an additional perioperative risk. Therefore, we felt it important to educate patients faced with upcoming surgery about the related risks in a manner that was personally tailored to their specific situation. The aim of increasing awareness was to capitalise on the potential 'teachable moment' of a surgical booking to encourage behavioural change [352-354].

Supportive needs

Even if patients are aware of obesity-related health risks, many need ongoing guidance about strategies and encouragement to keep motivated in changing their lifestyles to lose weight. Therefore, it was essential to provide timely, relevant information and regular interaction to improve patient skills and encourage a positive attitude towards behavioural change. Regular reminders are effective means of providing personalised, targeted support [46, 234].

7.3.2 Phase 2. Identifying Applicable, Underlying Theory

Besides SCT and HBM, theories relating to health behaviour include Theory of Planned Behaviour (TPB) [355], Self-determination Theory (SDT) [226], Transtheoretical Model (TM) [356], Community Organisation Model (COM) [357] and Diffusion of Innovation Theory (DIT) [358] (see the detailed comparison in Appendix C-2).

As HBM and TPB focus only on rational reasoning, ruling out unconscious, spontaneous behaviour and its emotional effects [342], and SDT is confined to explaining only behavioural motivations, none of these was considered suitable as a guide for the development of interventions that provide comprehensive healthcare support, such as health education and reminders [226]. The TM cannot explain how an individual person thinks he/she is ready to cope with a change or not, which would have caused difficulty in mapping intervention techniques to the behavioural determinant factors, so that weakened the explanatory capacity of the theory [185, 356]. The COM and DIT are both focused on initiatives to support community health promotion at the population level; therefore, they are not intended to guide the development of interventions to support behavioural change for individual patients [359]. Finally, SCT was selected to guide the design and development of the app.

Social Cognitive Theory explains an individual's behaviour through a reciprocal model of interactions among behaviour, personal factors, and social environment. It is a theory that synthesises a wide range of behavioural, cognitive and environmental determinants of behavioural change, such as self-efficacy, observational learning, outcome expectations and additional reinforcement [62]. This theory not only explains the behaviour of individuals under rational circumstances but also describes the influence and interaction of internal cognitive and external environmental influences on human behaviour [263], so it can be applied to guide the design of complex intervention for supporting the management of chronic conditions. Moreover, the SCT considers that people learn not only through their own experience, but also through imitating behaviours and the results of these behaviours. We felt that this was consistent with the purpose of this study to provide professional coaching to guide patients with obesity in preoperative weight loss and fitness improvement. Therefore, SCT was chosen as the most appropriate theory to guide the intervention design in our study.

7.3.3 Phase 3. Integrating Theory into the Prototype Design and Development

Social Cognitive Theory contains seven significant constructs: self-control, self-efficacy, expectations, expectancies, reinforcement, behaviour capacity and observational learning. All of these constructs were used to guide the design of conceptual intervention techniques and functions in the app (see Table 7-1).

Table 7-1 User needs, theoretical construct, conceptual intervention techniques and app functionalities

User needs	Theoretical construct	Conceptual intervention techniques	App functionalities
Motivational needs	Self-control	Let users set goals and encourage them to monitor their own behaviour towards the achievement of these goals	Build a functional module named "My Goals"
	Self-efficacy	Let users start by setting small, progressive and realistic goals	Provide some simple exemplar goals in "My Goals"
	Expectations	Let users know about the benefits of fitness for surgery	Provide an introductory video about the significance of fitness for surgery

User needs	Theoretical construct	Conceptual intervention techniques	App functionalities
	Expectancies	Allow users to track and monitor their own changes in weight, diet and physical activity. Provide feedback and let users evaluate what they value	Build a functional module named "My Steps" to record the number of steps each day. Build a functional module named "Surveys" and ask the users to complete these surveys. Send different push notifications according to different responses for feedback
	Reinforcements	Let users recognise and praise their achievements by specifying rewards	Make a trophy pop out once a user achieves his/her goal
Educational needs	Behaviour capacity	Teach users how to self-manage diet, physical activity, mood, and medical conditions	Translate relevant educational information into push notifications and send them to the users
	Observational learning	Let users watch some actions and outcomes of others' behaviour.	Provide an introductory video about how to achieve fit for surgery
Supportive needs	Reinforcements	Remind users to perform the behavioural change towards fitness for surgery	Send push notifications
	Reinforcements	Provide users with toolkits and resources that make the new behaviours easier to perform	Build a functional module named "My Resources"

Our app, Fitness4Surgery, consists of two interfaces (see Figure 7-3): a mobile interface for patients to self-manage their obesity and a Web-based portal for the healthcare administrators to edit, modify and update the content of push notifications, view patients' interaction with the mobile app and formulate text interventions.

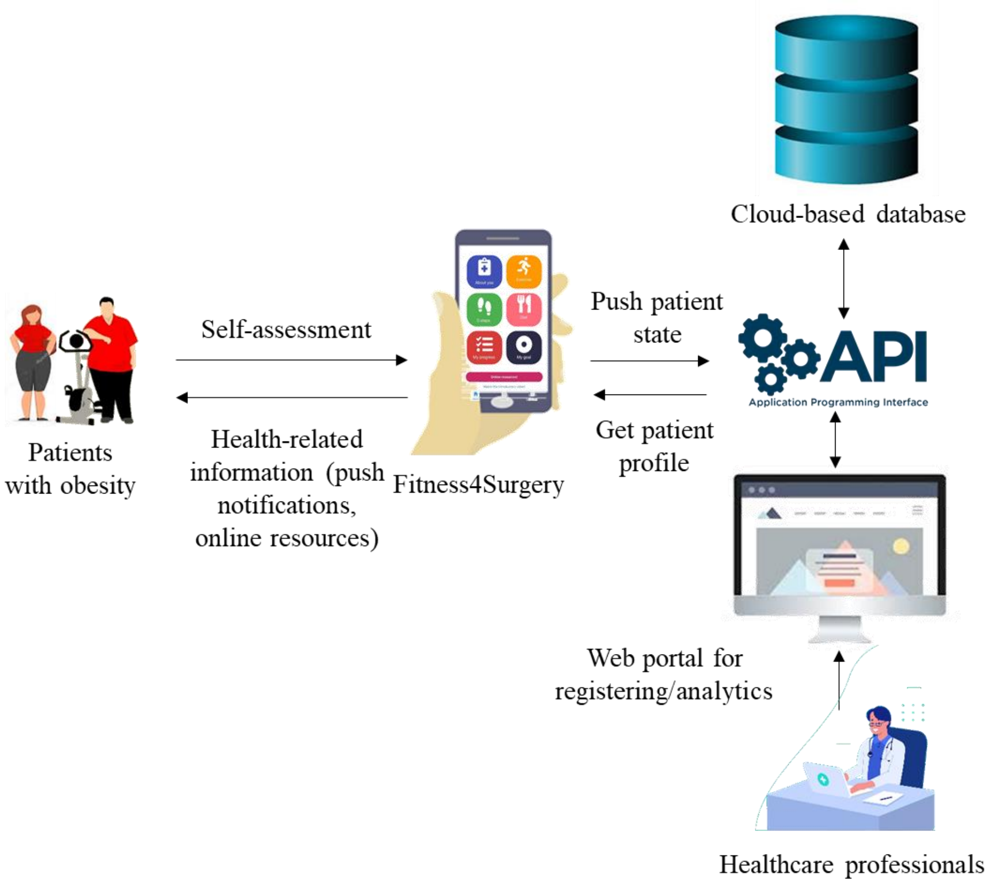

Figure 7-3 Working mechanisms of Fitness4Surgery

At the initial login to the app, patients are requested to answer the questionnaire surveys about their mobile phone usage experience, level of physical activity, diet, psychological well-being and preoperative health. The system will classify their level of function as 'high' or 'low' based on this data and will provide corresponding push notifications automatically. Ninety-six push notifications were designed by the four domain experts, i.e., the clinician, the clinical psychologist, the practising dietitian, and the exercise physiologist, based on advice on Australian Dietary Guidelines and Australia's Physical Activity and Sedentary Behaviour Guidelines and the research evidence [360-362] (see exemplar notifications in Table 7-2).

Table 7-2 Exemplar push notifications in the four domains

Domain	Content	Group of patients (Low or high risks)
Physical activity	Limit sitting time to a maximum of 30 minutes.	Low
	Limit sitting time to a maximum of 20 minutes.	High
Diet	Each day this week take a photo of your meal	High/Low
Psychology	You've got this! Stick with it. Set goals and take them one step at a time. It will be worth it!	High/Low
Medical advice	Reducing weight before your surgery can benefit your recovery and prevent unwanted complications. Work out your target weight by speaking to your GP or head to Get Healthy NSW by phone or online for more help.	High/Low

Patients with obesity are asked to set goals on the app. Once a goal is reached, a trophy pop will be displayed on the screen as a reward. They will be presented with links to existing health resources, such as the Heart Foundation (www.heartfoundation.org.au) and Get Healthy New South Wales (www.gethealthynsw.com.au). The patient-only use of the app keeps the data entered by the patient confidential. Patients can show the records to their doctors for discussion if they wish. There is a large variation in each clinician's approach to managing obesity [84]; therefore, the app did not cover this function. A notification will be automatically sent to patients every month to ask them to update their responses to the surveys.

7.3.4 Phase 4. Evaluating and Refining the Prototype Mobile App

Evaluation

The focus group participants reported two perceived benefits of the app: usefulness and ease of use. They also discussed areas that needed improvement for the four functional modules, that is, Survey, My Goals, My Resources, and push notifications (see Table 7-3).

Table 7-3 Data analysis of focus group discussion

Theme	Category	Topic	Exemplar quotation
Perceived benefits	Usefulness	Evaluate health conditions and health literacy before surgery	*"Well, yes, it's a good app, because it's got a lot of benefits; our progress, our goals, resources we can use, so, yes, it's probably good for everybody here." (Group1-05, female)*
		Access to health-related knowledge, skills and referrals	*" Looking at the resources that they've offered, it's a personal lifestyle app. (Group 2-05, male)"*
		Improving the patients' motivation	*"If it's just going to be a tool for yourself, perhaps an inspirational tool? "(Group 1-01 male)*
	Ease of use	Easy to use the system	*"Yes, I think it's good, it's quite easy to follow because I'm not very good at this, but I found it quite easy. "(Group 1-02, female)*
Improvement	Survey	Inflexibility	*"I physically cannot walk ten minutes, so my answer to the question is zero, but when I tried to complete the page, it's telling me it's incomplete, so all the information I put in is going to be junked (deleted)." (Group 2-03, female)*
		Ambiguity	*"Click on what? No, something's wrong." (Group 1-02, female)*
	My Goals	Insufficient feature	*" When you complete the survey at the start about you, yes, you've got a baseline, but over a period of time, the app is not collecting anything." (Group 2-02, male)*
		Suboptimal interface design	*"What about a graph about filling out or achieving the goals and seeing… something visual." (Group 1-05, female)*
		Lack of tracking	*"… is there a place where you can monitor your weight loss as you go?" (Group 1-06, female)*
	My Resources	Insufficient information and referrals	*"… it does need more resources in it" (Group 2-02, male)*
	Push notifications	Personalisation	*"Maybe there's an option that you can turn that setting on or off. … So, I like to stipulate what time (messages arrive)." (Group 1-06, female)*

Perceived benefits

Overall, the participants reported that the app could be useful, and they were looking forward to using this product for their surgical preparation. They felt that the app would help them (1) evaluate their health conditions and health literacy before surgery; (2) access health-related knowledge, skills, and referrals; and (3) improve their motivation by setting goals and rewarding their achievements. Some praised the ease of use of the app, even if they were not proficient in using smartphones.

Improvement

Survey. The participants raised two issues regarding the module. First, the operability of the system was not sufficiently flexible. They found that some questions in the questionnaire were irrelevant to their own situation. As all questions were mandatory, it was difficult to continue entering the data. Therefore, they suggested that some questions should be optional, which would allow them to skip the questions that were irrelevant to them or move through this section more quickly if they wished to. The second was semantic ambiguity. A few participants were confused about the meaning of certain questions and did not know how they should answer. They suggested modifying the expression of some questions to make them easier to understand.

My Goals. The participants raised three issues regarding the module. The first issue was monotony. They stated that it was boring because of its simplistic function and presentation, with an inadequate interface design. They suggested having some preset common goals as examples for users to choose from while retaining the flexibility to set their own goals. In particular, they felt that the color scheme was uninspired, with insufficient incentives provided to achieve their preset goals. They strongly requested the use of different colors, shapes, and icons to enrich the interface, with the provision of visual rewards once goals were completed, such as the appearance of animated trophies or fireworks. The second issue was functional. The participants felt that the timeframe for goals was important but not currently well defined. The third issue was the lack of a tracking mechanism. They felt disappointed because they could not monitor their progress toward achieving their goals. They also described several functions that they expected or found in other apps.

My Resources. The participants were generally satisfied with this module, except that some requested the provision of more psychological support. One participant requested a recipe section in the app.

Push notifications. The main focus of this discussion was on the optimal delivery time and frequency of these notifications. Some felt that daily notifications would help remind them of healthy routines, whereas others felt that excessive reminders could be overwhelming. One suggestion that was supported by the participants in both groups was that the app should allow users to set the timing that suited them to receive push notifications and that they could turn the reminder on or off themselves.

After focus group refinements

The refined design of the interface was simplified into three pages: Home, Messages, and Settings (see Figure 7-4a). The Home page consists of two major parts: user information and four buttons—My Goals, My Weight, My Surveys, and My Resources. The user information includes the name, profile, step count, and weight record. The display of weight at multiple points over time encourages users to progress toward their target weight.

In the My Goals module, the ability to select preset goals from a list was added to the free-text space (see Figure 7-4b). Once a goal is achieved, the user clicks once to record it and receives a star as a reward (see Figure 7-4c); 10 stars can be exchanged for a trophy and 10 trophies for a firework. A progress tracking function was also incorporated into the module.

A new module, My Weight, was added to the Home page, where users can read the changes in weight and BMI, both numerically and graphically (see Figure 7-4d). This allows users to track and monitor their own changes in weight, which addresses the application of expectancies in the SCT.

Apart from color and layout adjustments, the functions of My Surveys and My Resources remained unchanged (see Figure 7-4e&f). Users were able to answer the surveys at any time, and the results were recorded in a new area accessible for later review.

Figure 7-4 Screenshots of the key functional modules of the refined Home page of Fitness4Surgery

7.4 Discussion

7.4.1 Summary of Key Findings and Comparision with Existing Literature

To date, limited evidence exists regarding the use of a behavioral theory to guide the development of mobile services to support the patient self-management of chronic conditions, particularly in the context of prehabilitation for patients with obesity who are awaiting surgery. Guided by an existing framework for developing complex interventions to improve health and health care, this multidisciplinary study proposed a clinician-led, experience-based co-design approach and implemented it in developing a prototype mobile app, Fitness4Surgery, to provide guidance and support for patients with obesity to change lifestyle, lose weight, and improve fitness. The approach consisted of four iterative phases: understanding user needs, identifying theory, integrating theory into the design, and evaluating the prototype. In each phase, we engaged as many relevant stakeholders as possible for the consultation and gathered multiple sources of evidence from expert panel discussions, literature review, intervention mapping, and focus group discussions. Therefore, we adopted an evidence-based approach to design our mHealth service by drawing on experiences from clinicians, patients, researchers, and software developers.

To the best of our knowledge, this study is the first to articulate a detailed co-design approach that leverages the clinical experiences of clinicians and multidisciplinary teams to produce the initial prototype app. The prototype allowed the patients who participated in the focus group discussions to directly interact with the mobile app and experience its functions. This hands-on experience enabled them to draw on their needs and expectations for the mHealth app. The research output is useful for designing innovative digital interventions to provide just-in-time support for patients, which is low cost and easy to access [363]. This provides a useful alternative solution to address the service gap due to a shortage of funding and lack of human resources to provide these services face-to-face to vulnerable patients in the public health care system. mHealth services are also advantageous in the current period of the COVID-19 pandemic when social distancing is required [313, 314]. Compared with similar studies published, our research contributes three distinct innovations to advance the design of mHealth apps (see Table 7-4).

Table 7-4 A comparison of the contribution of this study and the existing literature

Author (Year) [Reference]	Aim	Design technique	Theory used	Theory mapping	User/Clinician design and test
Our study	To support patients with obesity to lose weight and improve fitness before surgery	Experience-based co-design	Social Cognitive Theory	Yes	Yes, expert panel discussion and focus groups
Smaradottir et al. (2020)**[141]**	To support chronic pain management	User-centered design	No	N/A	Yes, a co-creation workshop
Wachtler et al. (2018) **[316]**	To improve treatment allocation for depression	User-centered design	Theory of agent-oriented modeling	No	Yes, two focus groups
Morita et al. (2019) **[145]**	To support asthma self-management	User-centered design	No	N/A	Yes, semi-structured interviews
Duan et al. (2020) **[142]**	To improve patient compliance with hypertension self-management	Goal-directed design	Health Belief Model, Technology Acceptance Model	No	Yes, persona establishment (questionnaire, interview)
Fore et al. (2013) **[318]**	To support chronic care for pediatric inflammatory bowel disease	Goal-directed design	No	N/A	Yes, semi-structured interview
Woods et al. (2019)**[143]**	To support heart failure self-management	Nurse-led co-design	No	N/A	Yes, interviews and workshops
Martin et al. (2020)**[144]**	To improve obesity-related health behaviours of adolescents	Co-design	Behaviour change wheel, positive psychology, self-determination theory, nudging theory	No	Yes, workshop

First, only a few of the mHealth developments for supporting behavioural change in recent years have reported the use of a specific theory [142, 144, 316]. Our research analysed and compared common theories related to behavioural changes. In addition to guiding ideology at a high level, the theory-based design also involves the in-depth mining and analysis of all relevant constructs in theory and the mapping of the constructs to each user's needs to conceptualize a series of corresponding intervention techniques. These techniques were then converted to different real functionalities and were built into different function modules in the app, ensuring scientific rigour and practicality. The three proposed types of user needs are consistent with those addressed by similar mHealth interventions in alcohol and HIV areas [46, 87]. Huygens et al. conducted a comprehensive qualitative focus group discussion with patients with chronic conditions to explore their expectations and needs for using mHealth for self-management purposes. Patients with obesity perceived need fulfilment and disease control as determinants of their willingness to use the app, which reflects the advantages of ecological momentary assessment and intervention [195, 315].

Second, user interviews are traditionally conducted to gather user needs from the first stage [141-145, 316, 318], but in our study, clinicians proposed patient needs as the first step toward app content and design. This approach had two advantages. The first advantage was that clinicians' suggestions based on scientific and public health reports and their years of field observation were practical and valuable in guiding the design of intervention content and delivery. The second advantage was that patients are often not fully aware of the scientific background of their health conditions [364]. Providing patients with a prototype for a trial and revising the app based on their feedback made our use of resources as effective and efficient as possible. This agrees with the concept of formative research in which health care researchers or practitioners identify a community of interest, describe the features of the community associated with a specific medical issue, and define the initial needs, which are then tested in the population of interest [365]. The qualitative data collected in this stage can provide rich insights into the use of mHealth technology and the most effective engagement strategies [366]. Although we did not deliberately pursue information saturation as part of our qualitative approach, the ideas gathered from different disciplines had many common and overlapping points that guided app development. Focus group interviews with patients played an additional role. While suggesting several improvements, their attitude toward usefulness and ease of use of the app was positive, indicating the potential value of this app.

Patient feedback affirmed two indicators for measuring the level of acceptance in the technology acceptance model: usefulness and ease of use [367]. This reflects the scientific rigour of our design. The patients also indicated a limitation of the app, that is, insufficient information content and clarity, which is a known factor to affect the success of mHealth systems [135]. This reminded us about the importance of targeting information delivery to fit patients' health literacy. The main limitation of our prototype was a lack of personalization, which has been identified in previous studies [132, 133].

Third, most current app-based interventions specifically target bariatric surgery [55, 56]. Our research extends the scope of potentially effective mHealth interventions to any elective surgery, making the product much more generalisable to a wider audience.

7.4.2 Limitations and Future Work

This study had some limitations. First, participants in the focus groups were recruited via purposive sampling, so the diverse demographic groups were not evenly distributed. This could have led to a biased finding of the patient's level of acceptance and satisfaction with the mHealth app [368]. In the large scope trial, stratified sampling can be used to avoid this problem. Second, technology is rapidly changing. The current version of the app is relatively simple, despite meeting our identified requirements. Further development is required to develop intelligent and personalized functions. Third, the reuse of lessons may be limited by the small scope of the study at one site. However, the health informatics experts in our team have extensive experience in the development and evaluation of eHealth solutions. Moreover, the app design is underpinned by a carefully selected theory based on sound literature research, leading to robust functionality. Therefore, the design process is useful for other similar learning initiatives.

Future research will be conducted to evaluate the effectiveness of the app, with measures including user satisfaction and perioperative efficiency and outcomes. The app also has the potential to be used postoperatively and preoperatively to provide ongoing motivation and resources to users. This mHealth platform may be particularly useful when face-to-face health care options are limited, such as in regional and remote communities and during periods with social distancing restrictions. Moreover, the integration of the app-based system with existing electronic health records or tools used by clinicians in the health system could also be further investigated.

7.5 Conclusions

This study reports an innovative co-design approach with clinicians and patients to address the challenges facing participative co-design with patients' mHealth services that support their self-management of chronic conditions. It presents a detailed process to leverage the experiences of clinicians to produce the initial prototype app. Hands-on interaction with the prototype mHealth app in focus group discussions allowed the patients to effectively articulate their needs and expectations for the mHealth app. This research also presents a method to integrate theory into mHealth design, which addresses a missing link in the design of mHealth services that support the patient self-management of chronic conditions. The reported design approach can be generalized to the design of any mHealth services that aim to support the patient self-management of chronic conditions.

Summary

This chapter proposes a novel co-design approach and reports an action study in applying the knowledge from the research reported in Chapters 3-6 in a novel project that designed a mHealth application to support patient self-management of obesity in their preparation for elective surgery in Australia. It contributes to addressing Research Question 4. The results show that this innovative approach overcomes the traditional difficulty of gathering patient requirements in which the patients are likely to experience in comprehensively and accurately conceptualising their needs [364]. The study provided patients with a prototype for a trial and revising the app based on their feedback. It provided the patients with the opportunity to interact with a living app, facilitate them to voice their needs and envisage their desired functions of the mHealth app. The requirements gathered have also enabled the research team to further improve the design of the mHealth service. Therefore, the co-design approach had led to the effective and efficient use of resources for patient consultation in mHelth solution co-design.

Chapter 8

General Conclusion

8.1 Overview

This chapter provides a general conclusion of this PhD project. It starts with the recall of the research aim, objectives and questions. The answers to each of the four research questions are presented with a discussion of the contribution of this PhD project to both the body of knowledge and practical applications of mHealth services to support patient self-management of chronic conditions. This is followed by a self-reflection of the limitations of this study. The thesis concludes by a projection of the future research directions in designing and implementing mHealth service to support patient self-management of chronic conditions.

8.2 Summary of the Findings to Answer the Research Questions

This PhD project aims to comprehensively understand the application of mHealth services to support patient self-management of chronic conditions (see Section 1.2, Chapter 1). This aim is achieved by achieving four objectives: (1) synthesising research evidence about health outcomes of applying mHealth services to support patient self-management of chronic conditions and the essential components to achieve these outcomes, (2) determining the mechanism for applying mHealth services to support patient self-management of chronic conditions, (3) exploring critical factors and how these factors influence patients' intention to continue using mHealth services, and (4) applying the above findings to guide the design of a prototype mHealth service.

Four research questions (see Section 2.4, Chapter 2) have been answered to achieve these four objectives.

> *Research Question 1. What are the health outcomes of mHealth services to support patient self-management of chronic conditions and the essential components of mHealth services to achieve these outcomes?*

The answers to Research Question 1 are presented in Chapters 3 and 4. Chapter 3 systematically reviews 20 clinical trials of mHealth services to support patient self-management of unhealthy alcohol use [32, 90-95, 169-175, 182, 191-195] and extracts a conceptual framework for mHealth services, including five essential structural components - context, theory, content, delivery mode, and implementation procedure, to achieve three types of health outcomes - physiological, behavioural, and cognitive outcomes. Although this framework is extracted in the context of unhealthy alcohol use, it is also applicable to patient self-management of other chronic conditions because the mechanisms for chronic condition management remain the same, i.e., extrinsic guidance from the qualified healthcare providers, and intrinsic factors including self-awareness, knowledge and active management behaviour [8, 15, 84]. Compared with traditional face-to-face interventions, mHealth services are advantageous in helping patients proactively engage in self-management behaviour with a reduced demand for human labour, benefiting from automation of certain functions and electronic communication [196, 197]. The literature study suggests that sound evidence is yet to be sought about the effects of mHealth services in improving physiological and cognitive outcomes of chronic condition management.

Chapter 4 further investigates the application of theory in guiding the design, development and implementation of mHealth services reported in the literature. Six common theories are found that are often used to guide the management of chronic conditions by mHealth services - Health Belief Model, Social Cognitive Theory, Theory of Planned Behaviour, Self-determination Theory, Transtheoretical Model and Technology Acceptance Model. Most studies mention the name of the theory used, and several studies describe the relevant theoretical constructs. However, only a few studies provide details about the use of theory to select recipients, tailor interventions, measure constructs, or test mediation effects. No study reports refinement of the theories. Therefore, more attention needs to be given to the selection, application, and reporting of theory, and to assess the value of the applied theory to guide mHealth service design, implementation and evaluation in future studies [231]. These findings contribute to the design of mHealth services that support patient self-management of chronic conditions. Chapter 3 and Chapter 4 address the structure and outcomes of mHealth services from the perspective of Donabedian's healthcare quality evaluation model [41].

> *Research Question 2. What is the mechanism for mHealth services to support patient self-management of chronic conditions?*

The answers to Research Question 2 are presented in Chapter 5. The chapter reports the interview findings with 22 patients about their perceptions of a particular mHealth service used to support their self-management of hypertension. The study finds that the mHealth service extends the traditional hypertension care model beyond the hospital and clinician's office. The mechanism for mHealth services to support patient self-management of chronic conditions can be summarised in 6As: access, assessment, assistance, awareness, ability and activation. With its portability and digitisation, mHealth services provide patients with low-threshold access to communicating with their healthcare providers and receiving healthcare services to support their self-management behaviour. Such a structural change in health service delivery brings process improvement to assist patients' access to effective health assessment and healthcare assistance anytime, anywhere. The improvement in patient self-management awareness and ability, brought about by such structural and process changes, activate their self-management behaviours. Therefore, the comprehensive 6A framework developed from this qualitative research theorises the mechanism for the mHealth service to improve patient self-management of chronic conditions. The negative experiences of patients contribute to understanding the shortcomings of the service in its design and implementation. These findings have significant implications for further research and clinical practice. This study also contributes to understanding the process of mHealth services from the perspective of Donabedian's healthcare quality evaluation model [41].

> *Research Question 3. What are the critical factors, and how these factors influence patients' intention to continuously use mHealth services to support their self-management of chronic conditions?*

Chapter 6 addresses Research Question 3 by investigating the determinants and developing a predictive model to explain their relationship with patients' intention to continue to use mHealth services to support their self-management of chronic conditions. The research findings are acquired using a cross-sectional questionnaire survey method to empirical testing of the model in 121 hypertensive patients who use the same mHealth service as that reported in Chapter 5. It is found that the patients' continuous use intention is influenced by information quality, system quality and service quality through the mediation of perceived usefulness and user satisfaction. Patients' perceived health status also has a significant, positive influence on their continuous use intention. The validated model and questionnaire survey instrument are useful for the routine evaluation of patients' continuous use of mHealth services, for evaluating the operational effect of the mHealth program, and for routine identification of the performance of mHealth services in terms of information quality, mobile app usability, and technical and healthcare provider services. The findings also enrich the body of knowledge of mHealth continuous use to support patient self-management of chronic conditions.

Research Question 4. How to effectively apply the above-mentioned findings to the design of mHealth services to support patient self-manage chronic conditions?

Chapter 7 proposes a novel co-design approach and reports an action study in applying the knowledge from the research reported in the chapters above in a novel project that design a mHealth application to support patient self-management of obesity in their preparation for elective surgery in Australia, answering Research Question 4. The initial requirements for the mHealth services are proposed by the clinicians based on their experiences in guiding patients to self-manage chronic conditions. The co-design approach consists of four cyclic phases: understanding user needs, identifying applicable underlying theory, integrating the theory into the prototype design, and evaluating and refining the prototype mHealth services by patients. Expert panel discussion, literature review, intervention mapping and patient focus group discussions were used in these four phases, respectively. In Stage 1, the expert panel proposes three common user needs: motivational need, educational need, and supportive need. In Stage 2, the team selects the appropriate theory to guide the design of the mHealth service. In Stage 3, the team designs and develops the critical functions of the mHealth service, including automatic push notifications, online resources, goal setting and monitoring, and interactive health-related exchanges that encourage physical activity, healthy eating, psychological preparation, and a positive outlook for elective surgery. Push notifications are designed in response to a patient's risk level as informed by the person's response to a baseline health survey. In Stage 4, the prototype mHealth service is used in further requirement capturing from patients in two focus group discussions. This approach provides patients with the opportunity to interact with a living app, facilitating them to voice their needs and visualise their desired functions of the mHealth app. The requirements gathered have enabled the research team to further improve the design of the mHealth service.

8.3 Contribution

8.3.1 Theoretical Contribution

This PhD research project contributes to building the evidence base about the application of mHealth services to support patient self-management of chronic conditions. The specific theoretical contributions made include (1) identification of structural components and health outcomes of mHealth services to support patient self-management of chronic conditions; (2) explanation of the mechanisms for mHealth services to support patient self-management of chronic conditions; (3) identification of the factors impacting on patient's intention to continuous use mHealth services to self-manage chronic conditions; and (4) development of an innovative co-design approach to leveraging the clinical experiences of the clinicians to produce the initial prototype mHealth service, and the approach for engaging patients to effectively voice their needs and expectations for the mHealth service in the focus group discussion. The co-design approach can be generalised to the design of other mHealth services that aim to support patient self-management of chronic conditions.

8.3.2 Implications for Practice

This PhD project contributes to (1) providing practitioners with translatable insights about the strategies and practices into the design and implementation the similar mHealth products and services to support patient self-management of chronic conditions; (2) informing the relevant participating health organisations of the practice gap for improving their mHealth services; (3) identifying needs for the further development of mHealth services to support patient self-management of chronic conditions; and (4) providing guidance to the policymakers and health administrators to invest in mHealth services to manage the amounting resource challenges to support community-dwelling patients to self-manage their chronic conditions.

8.4 Limitations

In addition to the limitations mentioned in each chapter, the thesis, as a whole, is prone to the following limitations. Firstly, this PhD project investigates three different chronic conditions, i.e. unhealthy alcohol use, hypertension and obesity, at different research stages. The advantage of this research design is broadening the coverage of chronic conditions and generalisability of the findings when it is unrealistic to investigate all chronic conditions in one PhD study. The limitation is that each chronic condition has its specific characteristics, reducing the consistency of the study context. However, the study focus is mHealth services instead of a particular chronic condition; therefore, the pragmatic research approach is optimal, giving the available access to the mHealth services for this PhD project.

Secondly, regarding the sampling methods, purposive sampling is used for the selection of research participants, with access provided by the existing collaboration project, rather than randomly selecting organisations and participants [239]. This may be subjected to the sampling bias, i.e., the responses are not collected from a representative sample of the entire population of chronic conditions. The mediation method is to recruit participants with various demographic characteristics in terms of age, gender, education level, and occupation [237-239]. In the qualitative interview, data collection is concluded only when data saturation was reached, i.e., when no new issues are raised by the study participants.

Thirdly, the 6A framework and the model for continuous use of mHealth services are developed from the investigation in community-dwelling patients, managing by a tertiary hospital in China. In contrast, the prototype mHealth service support patients with obesity to lose weight and improve fitness is designed in Australia. The different medical systems and patient population between the two countries may affect the research progress and findings. In the actual process of the project in the two research sites, the PhD researcher makes a detailed observation, comparison, and recording of the research processes. Any variations are reported in time to the supervisors to seek feedback, exchange opinions and modify research strategies. The project progresses smoothly at the two research sites in the two countries, suggesting that the establishment of mHealth services for chronic condition management is a developing trend in different healthcare systems worldwide.

8.5 Recommendations to Future Research

Mobile health services are expected to support patient self-management of chronic conditions, especially in the current period of the COVID-19 pandemic when social distancing is required [313, 314]. But there is still a long way to go before mHealth services can be successfully integrated into routine healthcare delivery systems to play this role. First, the optimal way to design and implement personalized mHealth services to support patient self-management needs to be worked out [220, 317]. Since patients can benefit enormously from mHealth services, research needs to focus on their preferences and needs for these services, as well as facilitators for them to adapt to use the services. It is recommended that mHealth development needs to learn from other relevant research fields such as computer-supported collaborative work, group dynamics, peer support mechanisms, and social networks [234]. Second, the long-term use and effects of mHealth use also need to be understood [106, 108]. To ensure the benefits and sustainability of mHealth, further cooperations between industry and research organisations are encouraged to co-design, develop, implement, and evaluate mHealth services and generate lessons and insights for future successful integration of mHealth services into health delivery systems [48, 234]. Third, the economic challenge for mHealth services, i.e., the payment mechanism, still needs to be addressed. In the absence of sound evidence to prove cost-effectiveness, investors and decision-makers are not convinced about the usefulness of mHealth [369, 370]. Therefore, future research can focus on developing a sustainable business model to support the adoption and use of mHealth in routine healthcare systems. Fourth, future research also needs to be conducted as an empirical field study on the long-term effects of the mHealth services in the natural setting to derive generalisable insight for improving the practice of implementing mHealth services to support patient self-management of chronic conditions [371, 372].

8.6 Conclusions

This doctoral project contributes new knowledge and methods to the research field of mHealth services to support patient self-management of chronic conditions. It synthesises and extracts five essential structural components of mHealth services - context, theoretical base, content, delivery mode, and implementation procedure. It develops a 6A framework to explain the mechanisms for mHealth services to support patient self-management of chronic conditions, i.e., access, assessment, assistance, awareness, ability and activation. It suggests that mHealth services guided by behavioural theories can provide community-dwelling patients with easy "access" to health "assessment" and healthcare "assistance". The assessment results, i.e., vital signs and self-management behaviours, give patients "awareness" of their own health conditions and self-management performance, which also informs healthcare providers to provide patients with targeted assistance. Healthcare assistance includes health education and reminders of self-management behaviours, which can improve patients' self-management "ability" and overcome forgetfulness, "activating" their self-management behaviours. The effort for designing a mHealth service needs to be placed on crafting content (to improve information quality), designing useful functions and selecting the proper delivery mode (to improve system quality), and establishing effective implementation procedures (to improve service quality), guided by certain behavioural theories. This will ensure patients' perceived usefulness and satisfaction of the mHealth service, thereby provoking their intention to continuously use such services to support their self-management of chronic conditions. This project also reports an innovative co-design approach with the clinicians and patients to address the challenges facing participative co-design with patients of mHealth services that support their self-management of chronic conditions. The "hands-on" interaction with the prototype mHealth app in focus group discussions allowed the patients to effectively articulate their needs and expectations for the mHealth service. As demonstrated by the design case of a prototype mHealth service that supports patient self-management of obesity before elective surgery, the theories and methods developed in this PhD project can be generalised to the design of other mHealth services that aim to support patient self-management of chronic conditions in the future studies. Future research needs to focus on developing sustainable business models to support the adoption and use of mHealth in routine healthcare systems.

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Appendices

Appendix A Five Structural Components and Three Types of Health Outcomes of mHealth Services to support Patient Self-Management of Unhealthy Alcohol Use

Author(s) (Year) [Reference]	Context (patient characteristics; study setting; non-mobile co-intervention)	Theoretical base	Content	Delivery mode	Implementation procedure (length of intervention period; frequency; timing; baseline and follow-up assessment; other tricks)	Health outcome
Aharonovich et al. (2017)	AUD patients with HIV and use of drug, mean age: 51 years; Community-based setting; MI	NR (But the author claimed that the design of HealthCall app is theory-based)	(1) general queries about quantity of alcohol use, level of desire and commitment (2) personalized alcohol use graph (3) reinforcement of alcohol abstinence (4) daily "tip" video in which a counselor introduced skills to cut down alcohol use (5) referrals to call counsellor (6) reminders about sticking to the goal (7) a reminder if not use the App more than 24 hours	App (HealthCall-S)	60 days; Daily use (3mins/day); Morning, afternoon or evening decided by the participants but need to be consistent every day; Baseline assessment, 30-days assessment, 60-day assessment; Provision of the study smartphone with the data plan, provision of $40 worth of gift card per assessment visit	No significant outcome for all following measurements: reduced DD, reduced DDD
Gajecki et al. (2017)	AUD students, mean age: 25 years; University setting; NR	NR	(1) queries about alcohol use (2) a guideline for UAU (3) prevention skills for dealing with relapse, including risk simulation analysis, alcohol refusal, relax, positive thinking exercises and urge surfing training	App (TeleCoachTM)	12 weeks; Once weekly; NR; Baseline assessment, 6-week assessment, 12-week assessment; NR	SD (6-week assessment): IG<CG (*P*=0.037), no longer significant at 12-week assessment Frequency (6-week and 12-week assessments): IG<CG (*P*=0.041, *P*=0.034) No significant outcome for all following measurements: binge occasions, average eBAC, peak eBAC

Author(s) (Year) [Reference]	Context (patient characteristics; study setting; non-mobile co-intervention)	Theoretical base	Content	Delivery mode	Implementation procedure (length of intervention period; frequency; timing; baseline and follow-up assessment; other tricks)	Health outcome
Muench et al. (2017)	Risky drinking adults, mean age: 43 years; Community-based setting; Participants learned NIAAA guidelines for safe alcohol use and a document regarding how to respond mobile assessment	Social learning theory, health belief model	(1) queries about alcohol use (2a) loss-frame IG (LF): negative consequences of problem drinking (2b) gain-frame IG (GF): benefits of reducing drinking to safe guidelines (2c) statically tailored content IG (ST): tailored messages based on individual responses to baseline assessment (2d) tailored adaptive IG (TA) (2d1) individual tailored SMSs according to goal achievement (2d2) 2 SMSs with participant's name at the heaviest typical drinking times (2d3) a supportive message to response one of the automated system keywords sent by the participant	SMS	12 weeks; Once weekly (4 SMSs) for content (1) and each SMS would be resent 3 more times in next 2 hours if no response within 1.5 hour for all IGs Once daily for content (2a), (2b), and (2c) to LF, GF and ST&TA respectively at 6:00 pm Once weekly for content (2d1) and (2d2); Immediately for content (2d3); Baseline assessment, 12-week assessment; NR	Reduction of weekly SD: LF>MA (*P*=0.03), ST>MA (*P*=0.01), TA>MA (*P*=0.00) Reduction of weekly HDD: LF>MA (*P*=0.05), ST>MA (*P*=0.01), TA>MA (*P*=0.00) Increase of weekly abstinent days: GF>MA (*P*=0.03), ST>MA (*P*=0.04), TA>MA (*P*=0.02)
Riordan et al. (2017)	Risky drinking students, mean age: 18.5 years; University setting; NR	NR	Potential social consequence of UAU with colloquial tone	SMS	1 week (orientation week) 4 times week; Tuesday, Thursday, Friday and Saturday night at 19:00 and 21:00; Baseline assessment, 1-week assessment, 1-semester assessment; Provision of opportunity to win a	(1) In College 1: SD during orientation week: IG<CG (*P*=0.18), SD during the 1st semester: IG<CG (*P*=0.39) (2) In college 2: There are no significant differences in terms of alcohol use, but male students consumed significantly more alcohol

Author(s) (Year) [Reference]	Context (patient characteristics; study setting; non-mobile co-intervention)	Theoretical base	Content	Delivery mode	Implementation procedure (length of intervention period; frequency; timing; baseline and follow-up assessment; other tricks)	Health outcome
					mobile phone and prize of cash	than the female students (*P*<0.001).
Bock et al. (2016)	Risky drinking students, mean age: 22 years; College setting; NR	NR	(1) Alcohol facts (2) strategies to limit alcohol use and alcohol-related risks (3) motivation (4) a supportive message to response one of the automated system keywords sent by the participant	SMS	6 weeks; Once weekly (6 SMSs) for content (1)-(3), immediately for content (6); Thursday and Sunday evening (1 SMS for each day), Friday and Saturday evening (2 SMSs for each day); Baseline assessment; 6-week assessment; 12-week assessment; NR	No significant outcome for all following measurements: Drinking days per month HDD per month DDD eBAC Drinking days per past 2 weeks Negative consequence Strategies to limit drinking Brief situational confidence
Andersson (2015)	Risky drinking students, mean age: 23 years; University setting; NR	NR	(1) personalized feedback for assessment results (2) information on risk of negative consequences (3) information on SD (4) personalized recommendations for alcohol use (5) information for increasing tolerance and goal-setting	IVR	1 week for single IG and 4 weeks for repeated IG; Once daily; NR; Baseline assessment, 5-week assessment (4 weeks after intervention for single IG or 1 week after the intervention for repeat IG); NR	Reduction of peak eBAC: IG (total)>CG (*P*=0.023), IG (repeated)>CG (*P*=0.046) Reduction of AUDIT score: IG (total)>CG (*P*=0.000), IG (single)>CG (*P*=0.001), IG (repeated)>CG (*P*=0.001) DDD, frequency of drinking, mean BAC: not significant
Haug et al. (2015)	AUD patients, mean age: 47 years; Clinical setting; NR	Theory of planned behaviour	(1) personalized queries for monitoring drinking goals (2) personalized motivation of maintaining drinking goal according to their replies	SMS	6 months; Once weekly (weeks 1–8) and bi-weekly (weeks 10-26) for content (1), Immediately for content (2); Monday at 18:00;	No significant outcome for AUDIT-C score

Author(s) (Year) [Reference]	Context (patient characteristics; study setting; non-mobile co-intervention)	Theoretical base	Content	Delivery mode	Implementation procedure (length of intervention period; frequency; timing; baseline and follow-up assessment; other tricks)	Health outcome
			(3) a reminder to the counsellor if no SMS reply over 2 days		Baseline assessment; 6-month assessment Phone calls from the therapist for support, empathy and further help	
Riordan et al. (2015)	Risky drinking students, mean age: 22 years; University setting; NR	Social cognition models Social cognitive theory Theory of planned behaviour Self-determination theory Model of action phases	(1) social consequence of alcohol use (2) health consequence of alcohol use (3) queries about alcohol use	SMS	1 week (orientation week); Once daily; Tuesday, Thursday and Saturday night (3 SMSs) at 19:30 for content (1) Monday, Wednesday and Friday night (3 SMSs) at 19:30 for content (2) Thursday, Friday, Saturday and Sunday (4 SMSs) for content (3); Baseline assessment; 1-week assessment, 1-semester assessment; NR	Reduction of SD during Orientation Week (women only): IG<CG (P<0.05) Reduction of SD during the first semester (women only): IG<CG (P<0.05)
Suffoletto et al. (2015) Suffoletto et al. (2014)*	Risky drinking emergency department patients, mean age: 22 years; Hospital setting; MI	Health belief model, information motivation behaviour model, theory of reasoned action, theory of planned behaviour	(1) queries for reporting weekend drinking and binge plans (2) decision not to set a low-risk goal (2a) If "Yes", queries for reporting low-risk goal setting and feedback to	SMS	12 weeks; Twice weekly; Thursday for contents (1) and (2), Sunday for contents (3); Baseline assessment, 3-month assessment, 6-	HDD (at all assessments): IG<CG (significant intervention by time interaction) DDD (at all assessments): IG<CG (significant intervention by time interaction)

Author(s) (Year) [Reference]	Context (patient characteristics; study setting; non-mobile co-intervention)	Theoretical base	Content	Delivery mode	Implementation procedure (length of intervention period; frequency; timing; baseline and follow-up assessment; other tricks)	Health outcome
			promote reflection on drinking plan (2b) If "No", feedback to strengthen low-risk drinking plan/goal (3) queries for reporting alcohol use (3a) feedback to support low-risk drinking behaviour for adherence (3b) feedback to promote reflection on alcohol consumption for non-adherence		month assessment, 9-month assessment; NR	Binge drinking prevalence (at all assessment): IG<CG (significant intervention by time interaction) Alcohol-related injury prevalence (at 9-month assessment): IG<CG, not significant at others
Bendtsen & Bendtsen (2014)	Risky drinking students, mean age: 24 years; University setting; NR	Social cognition models, social cognitive theory, theory of planned behaviour, self-determination theory, model of action phases	(1) food for thought queries (2) task (3) challenges (4) reflective	SMS	4 weeks; 4 times weekly (4 SMSs); Wednesday for content (1), Friday for content (2), Saturday for content (3) and Sunday for content (4); Baseline assessment, 4-week assessment;	No significant outcome for all following measurements: Perceived drinking compared with peers Motivation to change
Brendryen et al. (2014)	Risky drinking adults, mean age: 39 years; Community-based setting; NR	NR	(1) personalized comparison of the reported drinking habits to the recommended gender-matched low-risk drinking guidelines and national gender-matched averages (2) 62 online sessions include four aspects: goal-setting and daily alcohol use track record, relapse prevention, emotion regulation and alcohol education.	SMS	6 months; 1 session daily for the first 56 sessions, 1 session weekly for sessions 57-60, 1 session monthly for sessions 61 and 62; Available on demand; Baseline assessment, 2-month assessment, 6-month assessment; NR	Weekly alcohol consumption: IG<CG (*P*=0.049) FAST score: not significant

Author(s) (Year) [Reference]	Context (patient characteristics; study setting; non-mobile co-intervention)	Theoretical base	Content	Delivery mode	Implementation procedure (length of intervention period; frequency; timing; baseline and follow-up assessment; other tricks)	Health outcome
Gajecki et al. (2014)	Risky drinking and AUD students, mean age: 25 years; University setting NR	Theory of planned behaviour	(1) register for alcohol use (2) eBAC result (3) notification (4) strategies to control alcohol use if a participant's alcohol use could lead to BAC>0.06%	App (Promillekoll)	7 weeks; Real-time use; Baseline assessment, 7-weeks assessment; NR	SD per week, binge occasions, eBAC per week, peak eBAC per month: not significant Drinking frequency (time-by-group interaction): IG>CG (*P*=0.001) Drinking frequency (male): IG>CG (P=0.001)
		Theory of planned behaviour	(1) a simulation of a planned drinking occasion for setting personal eBAC (2) register for alcohol use (3) eBAC result (4) comparison of planned eBAC with actual eBAC	App (PartyPlanner)		No significant outcome for all the above measurements
Gustafson et al. (2014)	AUD patients, mean age: 38 years; Nonprofit treatment organization setting NR	Self-determination theory	(1) anonymous discussion (2) question and answer (3) instant library (4) experience and knowledge sharing (5) web-links (6) distress easing (7) warning when near high-risk alcohol place based on GPS tech (8) brief survey to obtain patient data on negative affect, lifestyle balance, and recent substance use	App (A-CHESS)	8 months; Real-time use, once weekly for content (8); Baseline assessment, 4-month assessment, 8-month assessment, 12-month assessment; NR	HDD (4-month and 12-month assessments): IG>CG (*P*=0.002, *P*=0.003), not significant at 8-month assessment Prevalence and odds of abstinence (8-month and 12-month assessments, overall): IG>CG (*P*=0.004, *P*=0.002, *P*=0.003), not significant at 4-month assessment
Lucht et al. (2014)	AUD patients, mean age: 46 years Hospital setting NR	NR	(1) queries about alcohol use (2) referrals for further help (3) general automatic supportive feedback (4) a reminder to the therapist if no SMS reply more than 24 hours	SMS	8 weeks; Twice weekly; Monday and Thursday; Baseline assessment, 30-day assessment, 60-day assessment; Phone calls from the therapist for support,	DD: No significant outcome DDD: No significant outcome, but small effect in favor of IG HDD: No significant outcome

Author(s) (Year) [Reference]	Context (patient characteristics; study setting; non-mobile co-intervention)	Theoretical base	Content	Delivery mode	Implementation procedure (length of intervention period; frequency; timing; baseline and follow-up assessment; other tricks)	Health outcome
					empathy and further help	
Mason et al. (2014)	Risky drinking students, mean age: 19 years College setting; MI	Social network counselling	(1) queries about drinking facts (2) social norms (3) social risk (4) protective behavioural "boosts" if requested	SMS	4 consecutive days; 4-6 SMSs daily; NR; Baseline assessment, 1-month assessment; NR	Readiness to change alcohol use: IG↑, CG↓(P<0.01) AUDIT, SD, Alcohol expectations, Importance of changing, Confidence in ability to change, intensions to reduce alcohol use, taking steps to reduce alcohol use: not significant
Witkiewitz et al. (2014)	Risky drinking students with smoking, mean age: 20.5 years College setting; MI	Cognitive-behavioural treatment	(1) normative feedback (2) general or health information on alcohol use (3) protective behavioural strategies for alcohol use (4) alternative activities to alcohol use (5) urge-surfing (6) decisional balance for alcohol use	App (BASICS-Mobile)	14 days; Real-time use; NR; Baseline assessment, 14-day assessment, 1.5-month assessment; NR	No significant outcome for all following measurements: DDD HDD Young Adult Alcohol Problem Screening Test
Agyapong et al. (2013) Agyapong et al. (2012)*	AUD patients with unipolar depression, mean age: 48 years; Hospital setting NR	NR	(1) promoting alcohol abstinence (2) dealing with cravings (3) promoting medication adherence (4) providing general support	SMS	3 months; Twice daily (180 SMSs randomly sent); 10:00 and 19:00; Baseline assessment, 3-month assessment, 6-month assessment (published in 2013); NR	Cumulative abstinence duration (3-month and 6-month assessment): IG>CG (not significant); Alcohol Abstinence Self Efficacy Scale (3-month assessment): IG>CG (P=0.02), no longer significance at 6-month assessment; Days to first drink (6-month assessment): IG>CG (P=0.01), not significant at 3-month assessment; DDD (3-month and 6-month assessment): IG<CG (not significant)

Author(s) (Year) [Reference]	Context (patient characteristics; study setting; non-mobile co-intervention)	Theoretical base	Content	Delivery mode	Implementation procedure (length of intervention period; frequency; timing; baseline and follow-up assessment; other tricks)	Health outcome
Alessi & Petry (2013)	Risky drinking adults, mean age: 34 years; Community-based setting; NR	Contingency management	(1) Reminder about BrAC video submission (2) Reminder about possible compensation for valid on-time video	SMS	4 weeks; 1-3 times daily; From 8 am to 11 pm (concentrated in evenings from 6 pm to 11 pm and weekends); Baseline assessment, 4-weeks assessment; Monetary incentives	Percentage of n-BrAC: IG>CG (*P*=0.00) Longest abstinent days: IG>CG (*P*=0.00) Reduction of DD: IG>CG (*P*=0.00) Reduction of Alcohol Addiction Severity Index: IG>CG (*P*=0.01) Reduction of overall Drinker Inventory of Consequences: IG>CG (*P*=0.00) Reduction of DDD: not significant
Hasin et al. (2013)	HIV patients with risky drinking and AUD, mean age: 46 years Clinical settings; MI and training	NR	(1) queries about alcohol consumption (2) queries about reasons for drinking/abstinence (3) queries about mood (4) queries about medication adherence (5) queries about wellbeing (6) reminder about continuous participation if missed two consecutive calls	IVR	60 days (first session for 30 days repeated second session for 30 days); 1-3 minutes daily; Baseline assessment, 30-day assessment, 60-day assessment, 90-day assessment, 180-day assessment, 365-day assessment; NR	Reduction of DD (60-day assessment): IG>CG (*P*<0.01); IG>CG (*P*=0.03), no longer significance after 60-days

AUD: alcohol use disorder; CG: control group; DD: drinking day; DDD: drink per drinking day; HDD: heavy drinking day; IG: intervention group; IVR: interactive voice response; MI: motivational interviewing; NR: not reported; SMS: short message service

Appendix B Interview Guide

1. What was your initial reaction when you were recommended to use "Blood Pressure Assistant"?
2. Do you like to use it? Why or why not?
3. When was your hypertension diagnosed, and how was it managed before using the app "Blood Pressure Assistant"?
4. What do you know about hypertension before using the app "Blood Pressure Assistant"? Where did you acquire the information?
5. How long have you used the app "Blood Pressure Assistant" to manage your hypertension?
6. What did you usually use the app for? (Which functions did you use? Provide a whole list of the functions of the app for the participant to recognise) Do you find this app useful? Which functions are more useful? Why?
7. Which functions that you did not like to use? Why?
8. Do you have concerns or difficulties in using this app in your everyday life?
9. What improvements would you like to see?
10. What is your role in managing hypertension? What is your healthcare providers' role? What is the role of the app?
11. Are there any further issues that you would like to discuss with me?

Appendix C-1 Focus Group Questions

Introductory

- What phone do you use? iPhone, Android phone or windows phone
- What do you think about this app?

Features/functions

- Are there any features of this app that you would definitely NOT be interested in?
- What features or functions would you like to add to this app?

Push notifications

- How often would you like to receive push notifications from this app?
- At what time of the day do you prefer to receive these notifications? E.g. 12 midday, 4 pm or other time of the day

Expectation

- What goals do you expect to achieve by using this app?
- How do you think this app may help you to achieve these goals?

Concern and benefit

- Would you have any concerns about using this app?
- What benefits do you think this app may bring to you?

Information

- What type of information do you think the app should provide?

Use

- Do you think you will use this app?

App name

- What do you want to name this app?

Appendix C-2 Comparison of Behavioural (Change) Theories/Models

Theory (year)	Main focus	Key factors/procedures	Strengths	Limitations
Health Belief Model (1950s)	People's beliefs about health problems, perceived benefits of action and barriers to action, and self-efficacy explain engagement (or lack of engagement) in health-promoting behaviour. Used to explain and predict individual changes in health behaviours	Perceived susceptibility Perceived severity Perceived benefits Perceived barriers Cues to action Self-efficacy Modifying variables	Provide a theoretical framework for investigating cognitive determinants of health-related behaviours Make it easy to implement, apply, and test the model using simplified constructs	It does not account for a person's attitudes, beliefs, or other individual determinants that dictate a person's acceptance of health behaviour.
Social Cognitive Theory (1986)	learning occurs in a social context with a dynamic and reciprocal interaction of the person, environment, and behaviour. emphases social influence SCT considers the unique ways in which individuals acquire and maintain behaviour, as well as the social environment in which individuals conduct behaviours.	Reciprocal determinism Behavioural capability Observational learning Reinforcements Expectations Expectancies Self-efficacy Self-control	The concern with important human social behaviours based on the long-term accumulation of a large research record. Focused on important theoretical issues, e.g., the role of reward in learning, the stability of behaviour	It is not a fully systematised, unified theory. The theory is loosely organized, based solely on the dynamic interplay between person, behaviour, and environment. It is unclear the extent to which each of these factors into actual behaviour and if one is more influential than another.
Theory of Planned Behaviour (1985)	intention toward attitude, subject norms, and perceived behavioural control, together shape an individual's	Normative belief Subjective norm Control beliefs Perceived behavioural control	can cover people's non-volitional behaviour	is based on cognitive processing, it ignores one's needs prior to engaging in a certain action, needs that would affect behaviour regardless of expressed attitudes.

Theory (year)	Main focus	Key factors/procedures	Strengths	Limitations
	behavioural intentions and behaviours.	Behavioural intention Behaviour		
Self-determination Theory (1985)	people are motivated to grow and change by three innate and universal psychological needs. Focuses on the degree to which an individual's behaviour is self-motivated and self-determined.	Competence Relatedness Autonomy	distinguish between extrinsic and intrinsic motivation.	It lacks a developmental focus in that it does not look at the above-mentioned distinction in developmental terms.
Transtheoretical Model (1977)	uses the Stages of Change to integrate the most powerful principles and processes of change from leading theories of counselling and behaviour change;	Precontemplation Contemplation Preparation Action Maintenance Termination/Relapse	provides a framework for categorizing individuals' readiness to change their behaviour.	Ignores the social context in which change occurs The lines between the stages can be arbitrary, with no set criteria of how to determine a person's stage of change The model assumes that individuals make coherent and logical plans in their decision-making process when this is not always true. The Transtheoretical Model is applicable to only a single unhealthy behaviour and does not consider the impact of other confounding health behaviours.
Diffusion of Innovation Theory (1962)	explain how, why, and at what rate new ideas and technology gains momentum and spread over time.	Relative Advantage Compatibility Complexity Liability Observability	The DOI accelerate the adoption of many public health programs which are designed to changing the behaviour of social systems. It draws on the results of existing empirical research synthesizes them into a coherent and insightful perspective, so it is very practical in many fields.	It did not originate in public health, and it was not developed to explicitly apply to the adoption of new behaviours or health innovations. It does not foster a participatory approach to the adoption of a public health program. It works better with the adoption of behaviours rather than cessation or prevention of behaviours.

Appendix D Statement of Contribution of Collaborating Authors

This thesis is prepared in the style of Thesis by Compilation by the University of Wollongong.

Five peer-reviewed articles are included in this thesis. I am the first author of all these articles. Sixteen co-authors are involved in these publications. They are Ping Yu, Siyu Qian, Tingru Cui, Ning Deng, Fang Liu, Leonard Arnolda, Natalie Smith, Pascal Perez, Vida Bliokas, Yasmine Probst, Gregory Peoples, Mehrdad Amirghasemi, Lauren Houston, Yingping Guan, Zhenyu Zhang, and Nadeesha Pathiraja Rathnayaka Hitige.

Their percentage of contribution is indicated in the publications listed below.

This is followed by the signed co-author contribution declaration forms.

- **Published peer-reviewed journal articles:**

  1. Ting Song (80%), Siyu Qian (3%), Ping Yu (17%)

  Mobile health interventions for self-control of unhealthy alcohol use: systematic review. *JMIR mHealth and uHealth*, 2019, *7*(1), p.e10899.

  2. Ting Song (75%), Fang Liu (3%), Siyu Qian (3%), Ning Deng (3%), Tingru Cui (2%), Yingping Guan (2%), Leonard Arnolda (1%), Zhenyu Zhang (1%), Ping Yu (10%)

  A comprehensive 6A framework for improving patient self-management of hypertension using mHealth services: Qualitative thematic analysis. *J Med Internet Res*; 23(6):e25522.

  3. Ting Song (72%), Ning Deng (3%), Tingru Cui (3%), Siyu Qian (3%), Fang Liu (3%), Yingping Guan (1%), Ping Yu (15%).

  Measuring success of patients' continuous use of mobile health services for self-management of chronic conditions: Model development and validation. *Journal of Medical Internet Research, 23(7), p.e26670.*

4. Ting Song (70%); Ping Yu (5%); Vida Bliokas (3%); Yasmine Probst (3%); Gregory Peoples (3%); Siyu Qian (3%); Lauren Houston (3%); Pascal Perez (2%); Mehrdad Amirghasemi (1%); Tingru Cui (1%); Nadeesha Pathiraja Rathnayaka Hitige (1%); Natalie Smith (5%)

A clinician-led, experience-based co-design approach for developing mHealth services to support the patient self-management of chronic conditions: Development study and design case. *JMIR mHealth and uHealth*, *9*(7), p.e20650.

- **Published peer-reviewed book chapter:**

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